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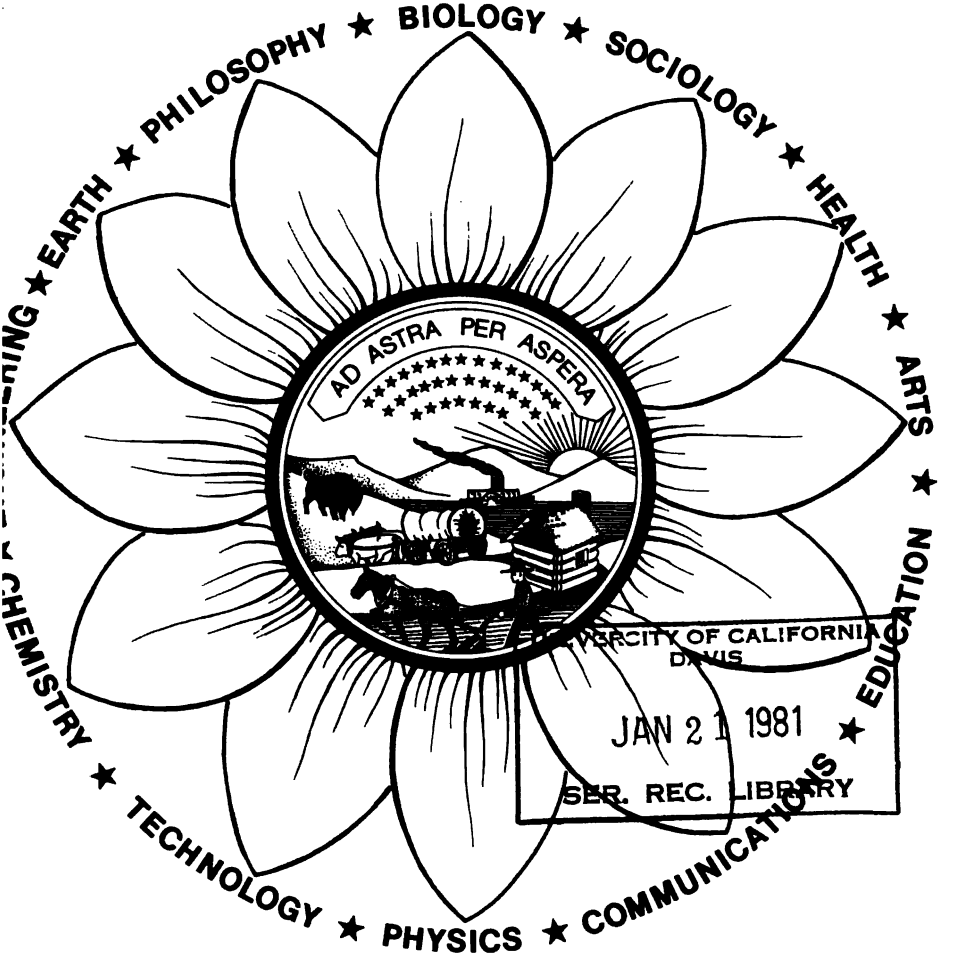


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# Unionacean Mussels, Past and Present, from Six Streams in Kansas and Oklahoma

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## ABSTRACT

Species of freshwater mussels (Bivalvia, Unionacea) were surveyed in six streams of south-central Kansas and north-central Oklahoma. Present fauna, fossil and archeological materials, and previous records were considered in an attempt to place the fauna in a historical perspective. Streams vary from those with a fairly intact fauna at present to those with a depauperate fauna.

## INTRODUCTION

In this study the present and some fossil and archeological occurrences of freshwater mussels (Bivalvia, Lamellibranchia, Unionacea) were surveyed in six streams in south-central Kansas and north-central Oklahoma. The six streams (Fig. 1) were Grouse Creek and Big and Middle Caney rivers, heading in Cowley, Elk and Chautauqua counties, Kansas, and Salt, Bird and Hominy creeks, heading in Osage County, Oklahoma. Only the segment of Big Caney River above its confluence with Middle Caney River and the segment of Bird Creek above its confluence with Hominy Creek were investigated.

All these streams originate in hilly areas. In the western part of the region considered are the Flint Hills, formed on rocks of Permian age, among which are strata of resistant cherty limestone. These strata contribute to extensive stream gravels and form stream bottoms in some places. Salt and Grouse creeks flow entirely within the Flint Hills. Big Caney River heads in the Flint Hills and receives its more important upper tributaries from these hills, which lie to the west of its valley in Kansas. The uppermost tributaries of Bird and Hominy creeks also head in the Flint Hills. However, the major parts of these streams (as well as that segment of Big Caney River in Oklahoma, considered here) flow through the Osage Hills in which sandstone strata of Pennsylvanian age are the chief contributors to stream gravels and where sandy bottoms commonly occur. Northward, in Kansas, the

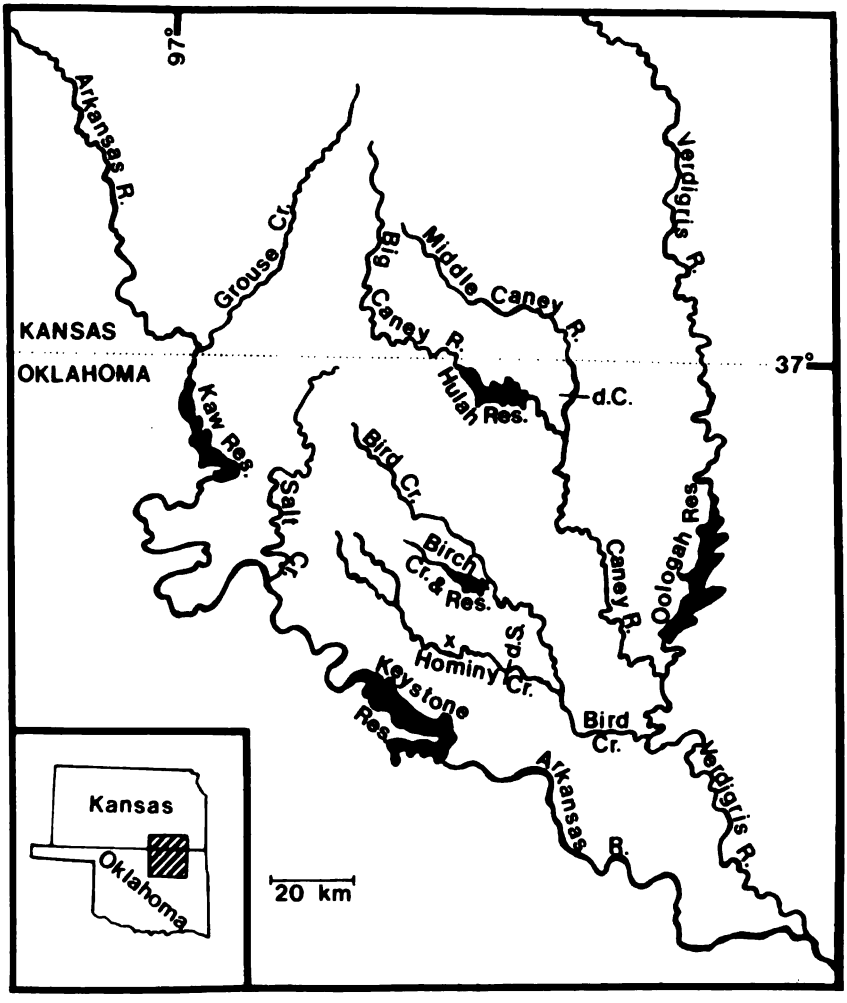


Fig. 1. Map of a part of southeastern Kansas and northeastern Oklahoma, showing streams mentioned in text. Abbreviations and symbols: Cr. = Creek; d.C. = dam that will impound Copan Reservoir; d.S. = dam that will impound Skiatook Lake; R. = River; Res. = Reservoir; x = Locality OS-114 (Big Hawk Shelter).

Chautauqua Hills (a continuation of the Osage Hills of Oklahoma) are drained in their southern part by Middle Caney River.

The watersheds of the streams in Kansas were settled by people of European origin in the late 1860's and in the 1870's. Stream valleys and some upland areas were cultivated in the late 1800's and early 1900's. Most of the previously cultivated upland has been returned to pasture in the past 50

years and in the past 20 years many valley fields have been sown to grasses so that there is less cultivated land in the watersheds than formerly in this century. It seems likely that siltation of these streams has been concomitantly reduced.

The watersheds in Osage County, Oklahoma, remained property of the Osage Indian Tribe until 1906, when individual allotments were made to tribal members (Mathews, 1961:772). Before that time little cultivation was practiced. Subsequently, lands were sold to non-Indians and cultivated tracts were developed, principally along valleys of the larger creeks and in level terrain in the upper part of the Salt Creek watershed. However, most of the upland of Osage County has remained range land to the present time.

There has never been any large-scale industrial development in the watersheds of the stream segments surveyed and the towns are all small; Pawhuska, the largest, presently has some 6000 inhabitants. Beginning about 1915, there were significant discoveries of petroleum in the region. Oil wells were drilled in watersheds of all six streams with those of Salt and Hominy creeks being most affected and that of Big Caney River the least affected.

In the 1960's a watershed program was initiated in the drainages of Big and Middle Caney rivers, which involved the construction of numerous small reservoirs on smaller streams in the systems. My observations indicate that this has resulted in more equable flow in streams with less flooding than formerly and more flow during droughts. This seemed to be the case in comparing flow for two summers during droughts, when I spent much time along Big Caney River: 1956, with prolonged intermittency, and 1978, with reduced flow only.

## METHODS

Numbering of stations where collections were made is explained in the list of localities, hereafter. Stations sampled ranged from 0.1 to 1.0 km in stream length. Some collections were made on tributaries of the streams considered but these are not listed, as the uppermost segments of the streams, proper, seemed adequately to characterize habitats and faunas of smaller creeks of the systems. Stations were visited only during summer months, between 1969 and 1979, with years indicated in the list of localities. Specimens were collected by hand. Species taken are indicated in Tables 1–4.

At many stations bank sediments contained fossilized shells of mussels, which contributed to knowledge of former inhabitants of the streams. No radiometric dates were obtained from these fossils, although these would have been desirable. The sediments seem surely to be of relatively late, Holocene age, probably between a century (pre-entrenchment) and a few thousands of years old. None of the deposits mentioned contained artifacts

Table 1. Species of unionacean mussels taken at ten localities in Big Caney River and its floodplain deposits. Locality designations are explained in the section "Localities of Collections." Abbreviations concerning specimens are: L = living or with flesh adhering; F = fresh with nacre and periostracum in well preserved condition; W = weathered, probably fossil in many cases; * = fossil (in place) from streambank deposits. L and F are judged to be species presently living at locality. Only one of the designations L, F or W is used per given locality and employed, as applicable, in that order. All fossil occurrences are indicated.

| | Localities | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | C-1 | C-2 | C-3 | C-4 | C-5 | C-6 | C-7 | C-8 | C-9 | C-10 |
| *Amblema plicata* | | * | F | L* | L | L* | L* | L* | F | W |
| *Anodonta grandis* | | L | L* | L* | F | L | L | F | F | F |
| *Anodonta imbecilis* | L | F | F | F | F | F | L | F | | |
| *Carunculina parva* | | F | | F* | F | L | | | | |
| *Fusconaia flava* | | * | * | * | L | L* | L* | W* | | F |
| *Lampsilis ovata* | | F | L | L* | L | L* | L* | L* | F | F |
| *Lampsilis radiata* | * | * | * | * | L | L* | * | * | | |
| *Lampsilis rafinesqueana* | | | | | | | * | W | W | |
| *Lampsilis teres* | | | * | * | W | L* | L* | L* | F | F |
| *Lasmigona complanata* | | | | | L | L | L | L | L | F |
| *Lasmigona costata* | | | | | | * | | | | |
| *Leptodea fragilis* | | | | | | L | L | L | L | F |
| *Ligumia subrostrata* | L* | L* | F* | L* | L | L* | L* | L* | | F |
| *Obliquaria reflexa* | | | | | | L | L | | | F |
| *Proptera laevissima* | | | | | | L | | F | L | F |
| *Proptera purpurata* | | | | * | | L | L | L* | F | F |
| *Ptychobranchus occidentalis* | | | | * | | * | W* | W* | | |
| *Quadrula pustulosa* | | | | F | F | L* | L | L* | F | L |
| *Quadrula quadrula* | | | | F | L | L | L | L | L | F |
| *Strophitus undulatus* | | L | L* | L | L | L* | L* | L* | | |
| *Tritogonia verrucosa* | | | | * | L | L* | L* | L* | L | F |
| *Truncilla donaciformis* | | | | | | | | | F | F |
| *Truncilla truncata* | | | | | | L | L | L | L | F |
| *Uniomerus tetralasmus* | L | | | | | L | | | | |
| Total, present fauna (L + F): | 3 | 6 | 6 | 9 | 13 | 20 | 16 | 15 | 13 | 15 |

attributable to presence of European man in the area. Fossils are indicated by asterisk in Tables 1–4. Through the courtesy of Donald Henry, University of Tulsa, mussels obtained in three archeological excavations in the drainages of Hominy and Bird creeks were examined (localities designated "OS" in list of localities). Radiocarbon determinations were available for Loc. OS-114 (referred to, hereafter, as Big Hawk Shelter) and ranged from approximately 200 A.D. to 1500 A.D. (Table 5).

Specimens from each locality are deposited in collections of the Department of Biological Sciences, University of Texas at El Paso. Representatives of species taken in each stream were deposited with the National

Table 2. Species of mussels taken in Grouse Creek and its floodplain deposits. Abbreviations and symbols are explained in Table 1.

| Species | Localities | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | G-1 | G-2 | G-3 | G-4 | G-5 | G-6 | G-7 | G-8 | G-9 |
| *Amblema plicata* | | L* | L* | L | L | L | L* | L* | W |
| *Anodonta grandis* | | L* | L | L | L | L | L | F | F |
| *Anodonta imbecilis* | | F | | | | F | L | | |
| *Carunculina parva* | | F | | F | F | | | F | |
| *Fusconaia flava* | | * | W | W | L | L | W* | W* | |
| *Lampsilis ovata* | | * | L | L | L | L | F | F | L |
| *Lampsilis radiata* | | * | L* | L | L | L | W* | F | |
| *Lampsilis teres* | | W | L | F | L | L | W | L | |
| *Lasmigona complanata* | | | L | F | L | L | F | F* | L |
| *Leptodea fragilis* | | | | | | | L | L | L |
| *Ligumia subrostrata* | F | L* | L* | L | L | L | L* | L | W |
| *Obliquaria reflexa* | | | | | | | | | * |
| *Proptera laevissima* | | | | | | | | | F |
| *Proptera purpurata* | | W | W | W | F | W | W | W | L |
| *Quadrula pustulosa* | | * | F* | L | L | L | F | L* | W |
| *Quadrula quadrula* | | | L* | L | L | L | F | L | L |
| *Strophitus undulatus* | | | L | L | L | L | L | L | |
| *Tritogonia verrucosa* | | | F | L | L | L | L | L* | L |
| *Uniomerus tetralasmus* | F | | | | | | | | |
| Total (L + F): | 2 | 5 | 11 | 12 | 14 | 13 | 11 | 13 | 8 |

Museum of Natural History and with the Museum of Ohio State University. Representatives from the streams in Kansas were deposited with the State Biological Survey of Kansas, Lawrence.

Nomenclature employed follows that of Burch (1975) except for my use of *Ligumia subrostrata* (not *nasuta*) and of *Proptera* (not *Leptodea*) *laevissima*.

## Previous Studies

There have been few previous records of unionaceans from the streams surveyed. Murray and Leonard (1962:Figs. 3, 35, 38) mapped *Amblema plicata*, *Ligumia subrostrata* and *Lampsilis radiata siliquoidea* in the Big and/or Middle Caney systems and recorded (p. 122) *Leptodea fragilis* from Silver Creek, a tributary of Grouse Creek.

Liechti and Huggins (1977) reported *Anodonta imbecilis*, *Lampsilis ovata*, *Ligumia recta* and *Truncilla truncata* from Big Caney River, 2.4 km west of Elgin, Chautauqua County, Kansas. From the same stream near Cedar Vale (my Loc. C-6) they reported *Tritogonia verrucosa*, *Strophitus undulatus* and *Proptera alata*. Guenter Schuster of the State Biological

Table 3. Species of mussels taken in Middle Caney River and Bird Creek. Abbreviations and symbols are explained in Table 1. Conditions for collecting were poor at Loc. M-4.

| | Localities | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | M-1 | M-2 | M-3 | M-4 | M-5 | M-6 | B-1 | B-2 | B-3 | B-4 | B-5 | B-6 | B-7 |
| *Amblema plicata* | | W* | L* | W | W | | | W* | L | F | W | W | |
| *Anodonta grandis* | W | F | F* | L | F | F | | L | F | L | F | | |
| *Anodonta imbecilis* | F | F | L | | | | F | F | | L | | | |
| *Carunculina parva* | | F | F | | | | F | F | F | F | F | | |
| *Fusconaia flava* | | W | W* | | | | * | W | W | | | | |
| *Lampsilis ovata* | | | W* | W | | W | * | | | | | | |
| *Lampsilis radiata* | * | W | W* | | | | * | W | W | W | | | |
| *Lampsilis teres* | * | L | L* | | L | L | | L | L | F | L | L | F |
| *Lasmigona complanata* | | L | L | F | L | L | * | | | | L | F | F |
| *Leptodea fragilis* | | L | L | | L | L | | | | | L | L | L |
| *Ligumia subrostrata* | L | L | L* | L | L | F | L* | F | L | L | L | F | L |
| *Proptera laevissima* | | | | | | F | | | | | L | F | F |
| *Proptera purpurata* | | L | | W | L | L | | | | | W | F | |
| *Quadrula pustulosa* | | | | | | F | | | | | F | | |
| *Quadrula quadrula* | | | F | F | L | L | | | | | | | F |
| *Strophitus undulatus* | | | * | | | | | | | | | | |
| *Tritogonia verrucosa* | | | W | | F | L | | | | | | W | L |
| *Truncilla donaciformis* | | | | | | | | | | | L | | |
| *Truncilla truncata* | | | W | | | W | | | | | | | |
| *Uniomerus tetralasmus* | | | | | | | | L | F | L | | | |
| Total (L + F): | 2 | 8 | 9 | 4 | 8 | 10 | 3 | 6 | 6 | 7 | 9 | 6 | 7 |

Survey of Kansas has reidentified (pers. comm., 10 August 1978) the specimens of "*Ligumia recta*" as *Lampsilis teres* and the specimens of "*Proptera alata*" as *Proptera purpurata*. A record of "*Elliptio complanatus*" from Big Caney River, west of Elgin, by Mackie and Huggins (1976:Table 2) seems to be in error as *E. complanata* is a species of drainages far to the east and northeast of Kansas (Burch, 1975:11).

The only previous records, known to me, for the streams surveyed in Oklahoma are those reported by Isely (1924), based on his survey of the unionaceans of eastern Oklahoma in 1910–1912. He sampled the lowermost part of Salt Creek and Bird Creek at Catoosa and Nelagoney.

In the following sections, species are categorized in relation to their past and present distributions, proceeding from extirpated species, progressively, to better represented species.

## Extirpated Species

Four species formerly existed in some streams of the area but seem to have been extirpated.

Table 4. Species of unionacean mussels taken in Salt Creek and Hominy Creek. Abbreviations and symbols are explained in Table 1.

| | Localities | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | S-1 | S-2 | S-3 | S-4 | S-5 | S-6 | S-7 | H-1 | H-2 | H-3 | H-4 | H-5 | H-6 |
| *Amblema plicata* | | W | L | L* | F | W | W | | W | * | W | * | |
| *Anodonta grandis* | | F | F | L* | F | | F | | | | | | |
| *Anodonta imbecilis* | | | L | L | | L | F | F | | | | | |
| *Carunculina parva* | F | L | F | | | F | | F | F | | | F | |
| *Fusconaia flava* | | | | * | W | | * | | | | | | |
| *Lampsilis ovata* | | | | * | | | | | | | | | |
| *Lampsilis radiata* | | | | * | W | * | | | | * | | | |
| *Lampsilis teres* | | F | L | L* | L | L | L | | W | * | L | L | |
| *Lasmigona complanata* | | L | F | L | F | F | L | | | | L | L | |
| *Lasmigona costata* | | | | * | | | | | | | | | |
| *Leptodea fragilis* | | L | L | L | L | L | L | | L | F | L | L | L |
| *Ligumia subrostrata* | F | L | L | L* | F | F | W | L | F | L | L | L | |
| *Obliquaria reflexa* | | | | * | | | W | | | | | | |
| *Proptera laevissima* | | | | | F | F | F | | | F | F | | L |
| *Proptera purpurata* | | F | F | L* | F | L | L | | | * | | | |
| *Quadrula pustulosa* | | | | | | L | L | | | | | | |
| *Quadrula quadrula* | | | F | L* | F | F | L | | | | | | |
| *Tritogonia verrucosa* | | | | * | | | W | | | * | | | |
| *Truncilla donaciformis* | | | | | | | | | | | | L | |
| *Uniomerus tetralasmus* | | | | | | | | L | F | F | | | |
| Total (L + F): | 2 | 7 | 10 | 9 | 9 | 10 | 9 | 4 | 4 | 4 | 5 | 6 | 2 |

*Lasmigona costata* (Rafinesque). The Fluted Mussel was represented only by fossils found in streambank deposits along (1) Big Caney River at Loc. C-6 and (2) Salt Creek at Loc. S-4 and at a nearby, unnumbered locality. These represent isolated, western records as compared to the present known distribution of this species. Neither Isely (1924:Table 2), in Oklahoma, nor Murray and Leonard (1962:86), in Kansas, recorded it west of the Neosho (Grand) River drainage. Schuster (1979) did not take it in a survey of the upper Verdigris River system in Kansas.

*Ptychobranchus occidentalis* (Conrad). A single fresh shell (132 × 70 mm) of this species from Big Caney River is in collections of the National Museum of Natural History. This specimen (USNM 424940) was collected by C. E. Burt in October, 1932, at "Camp Ta-la-hi, 5 mi. SE of Cedarvale." As no fresh shells or living specimens have been found in Big Caney River in this survey it is deemed likely that the species has become extinct since 1932, perhaps during the drought of the 1930's when the stream suffered from depleted discharge and prolonged intermittency. Burt may have regarded the specimen noted above as a rarity already in 1932, as he saw fit

Table 5. Unionacean shells (numbers of single valves indicated) from archeological locality OS-114 (Big Hawk Shelter). Radiocarbon determinations (on charcoal) are indicated under "Date, A.D." and are by laboratories of Southern Methodist University. Dates are based upon Libby half-life of 5568 ± 30 years and are not recalibrated to calendar years.

| Level (in cm) | Date, A.D. | *Amblema plicata* | *Fusconaia flava* | *Lampsilis ovata* | *Lampsilis radiata* | *Lampsilis teres* | *Lampsilis* sp. | *Lasmigona complanata* | *Ligumia subrostrata* | *Proptera purpurata* | *Quadrula pustulosa* | *Quadrula quadrula* | *Strophitus undulatus* | *Tritogonia verrucosa* | Unidentified | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0–10 | | 5 | 3 | | | | | | 4 | | | | | | 1 | 13 |
| 10–20 | 1530 ± 70 | 13 | 2 | | | 6 | | | 1 | | 1 | | 1 | | 1 | 25 |
| 20–30 | 1230 ± 20 | 29 | 3 | 4 | | 3 | | | 3 | | | | 1 | 7 | 2 | 53 |
| 30–40 | 1053 ± 51 | 35 | 4 | 3 | 2 | 18 | | 2 | 4 | | 3 | 1 | | 8 | 3 | 82 |
| 40–50 | 1179 ± 44 | 55 | 6 | 7 | 5 | 20 | 4 | 1 | 8 | | 2 | 1 | | 6 | 12 | 127 |
| 50–60 | 819 ± 56 | 50 | 11 | | 2 | 12 | | | 8 | | 4 | | | 1 | 5 | 93 |
| 60–70 | 660 ± 50 | 37 | 7 | 2 | 3 | 3 | | | 10 | | 4 | | | 7 | 2 | 75 |
| 70–80 | 628 ± 48 | 78 | 8 | 2 | 3 | 9 | | 1 | 5 | | 2 | | 1 | 9 | 7 | 125 |
| 80–90 | 412 ± 83 | 28 | 9 | 5 | 2 | 8 | 1 | | 7 | | | | | 2 | 5 | 67 |
| 90–100 | 332 ± 60 | 7 | 3 | 3 | 1 | 3 | 2 | | 3 | | | | | | 2 | 24 |
| 100–110 | 200 ± 70 | 2 | 2 | | | | | | | | | | | | | 4 |
| 120–130 | | | | | | 1 | | | | | | | | | | 1 |
| Totals: | | 339 | 58 | 26 | 18 | 83 | 7 | 4 | 53 | 1 | 16 | 1 | 3 | 40 | 40 | 689 |

to single it out for deposition in the National Museum. The species must formerly have been well represented in the middle segment of Big Caney (Table 1). Elsewhere in Kansas, living specimens have been reported from a single locality on Spring River, Cherokee County (Branson, 1967:288; Liechti and Huggins, 1977:25) and collected there by me (1 August 1972). Shells (some fresh) were found by Schuster (1979:20) in the upper Verdigris River.

*Lampsilis rafinesqueana* Frierson. Specimens of this species were identified by David Stansbery, Ohio State University. This species has sometimes been ascribed to *Actinonaias carinata* (Barnes) or to *A. ligamentina* (Lamarck). Only weathered valves and fossils of this species were found and only on Big Caney River at Locs. C-7, C-8 and C-9 (and elsewhere near these stations). The species now seems extinct in Big Caney River. Schuster did not find it in his survey of the upper Verdigris system (1979:23) and deemed it to be extirpated there.

*Ligumia recta* (Lamarck). Two greatly weathered valves, seemingly of this species, were found by Charles Cope in gravels of Big Caney River between stations C-7 and C-8, 1.5 km S Hewins, Chautauqua County, in June, 1979. This seems to be a sensitive species, especially vulnerable to

extirpation. Schuster (1979:17) failed to take it in his survey of the upper Verdigris system. He concluded that it had become a rare species in Kansas.

## Species Found Living Only in Big Caney River

*Obliquaria reflexa* Rafinesque and *Truncilla truncata* Rafinesque were found living only in Big Caney River. Numbers of specimens of both of these species seem to have increased at Loc. C-7 since 1970. These species were not found at Loc. C-6 in early years of this survey but appeared there in the mid-1970's with small specimens first observed. Possibly both species are increasing in numbers in the stream and extending their range upstream. This may be in response to changed stream conditions (such as more stable discharge) brought about by the watershed program, mentioned above, involving construction of small reservoirs on headwaters.

Fossils of *O. reflexa* were found at the lowermost locality (G-9) on Grouse Creek and a weathered valve of *T. truncata* was found in stream gravels 1.75 km north of G-9. Weathered shells and fossils of both *O. reflexa* and *T. truncata* were found in Walnut River in western Cowley County, Kansas. Weathered shells of *T. truncata* also occur in Middle Caney River (Table 2). Isely (1924:Table 2) noted presence of both species in lowermost Salt Creek and I found weathered shells and fossils of *O. reflexa* on Salt Creek in this survey (Table 4). Thus, these seem to be species that formerly occurred in the lower parts of most or all of the stream segments surveyed and which have suffered marked restriction of range except in Big Caney River.

## Species Found Living Only in Big Caney River and Grouse Creek

Four species were found living only in Big Caney River and Grouse Creek, although all occurred, in the past, in one or more of the other streams surveyed.

*Fusconaia flava* (Rafinesque). The Pig-Toe Mussel was found, as a fossil, often abundantly in all six streams surveyed and from the three archeological sites noted above (see Table 5). It was reported from two stations (Catoosa and Nelagoney) on Bird Creek by Isely (1924:Table 2). In the present survey, *F. flava* was found living only in the middle segments of Big Caney River and Grouse Creek. Even in these areas, living specimens or fresh shells were rare, except at Loc. C-5, where they were noted as common on 2 August 1978. Living specimens seemed to be more frequently found in the later than they were in the earlier 1970's on Big Caney River.

*Fusconaia flava*, once an abundant species in the six streams, seems to have been especially intolerant of changing stream environments, culminating in its probable extinction in all but two of the streams. It will be of interest to observe whether it will increase in numbers in Big Caney River in the future.

*Lampsilis ovata* (Say). The Pocketbook Mussel was common in the middle segments of Big Caney River and Grouse Creek. Weathered shells were found at several stations on Middle Caney River (as they were also in gravels of the Walnut River in western Cowley County, where the species no longer seems to occur). Isely (1924:Table 2) recorded it from lowermost Bird Creek at Catoosa and I found fossils in streambank deposits at Loc. B-1 on upper Bird Creek and at Loc. S-4 on Salt Creek. In archeological deposits of Big Hawk Shelter, *L. ovata* was found at several levels (Table 5). Thus, it seems formerly to have occurred much more widely in the region than it does at present, perhaps when conditions in other streams more closely approximated those in which it persists in Grouse Creek and Big Caney River.

*Lampsilis radiata siliquoidea* (Barnes). The Fat Mucket Mussel was taken at several stations on Grouse Creek, being most common at Locs. G-5 and G-6. It was less common in Big Caney River and was found only at Locs. C-5 and C-6. It formerly must have been a common species in the upper and middle parts of all six streams as it is an abundant fossil in their bank sediments. It occurs at all three archeological sites but most abundantly at OS-135 on Birch Creek, a small tributary of Bird Creek. It seems clearly to have suffered severe restriction of range, marked especially by its disappearance from upstream waters (see Tables 1–4). Its extirpation from four of the six streams suggests that it is a sensitive species, whose future existence here may be in jeopardy. Schuster (1979:16) did not find *L. r. siliquoidea* in a survey of Elk, Fall and upper Verdigris rivers in Kansas. However, I have taken it between his collecting sites 14 and 15 on Elk River at Elk Falls. It now seems to be restricted to a short middle segment of Elk River as it is in Big Caney River and Grouse Creek. In contrast to recent findings, Scammon (1906:288) found it to be abundant in eastern Kansas in the early years of this century. Such former abundance accords with the fossil evidence noted above.

*Strophitus undulatus* (Say). The Squaw-Foot Mussel was a common species in the upper and middle parts of Grouse Creek and Big Caney River but rare or absent at lower stations on both streams. It was not found living in the other streams surveyed but occurred at three levels in the archeological deposits of Big Hawk Shelter and at one level at OS-138 along Hominy Creek (Table 5). Fossils were found at Loc. M-3 on Middle Caney River. These records indicate wider distribution in the past, but now greatly reduced to stream segments with especially favorable habitats.

The four species discussed in this section are nearing, in the streams surveyed, the westernmost limits of their range in the Arkansas River System. Thus, natural restraints may make their existence here precarious so that the addition of further (possibly relatively slight) deleterious factors might tip the balance towards extirpation. Only 150 km to the east, the

situation may remain more as it was in the survey area a century ago. There, in the drainage of Spring River, Branson (1967:287) noted that *Lampsilis radiata siliquoidea* (=his *L. luteolus*) "Both in numbers and distribution . . . is the most common species encountered . . . ." Fossils suggest that this description might have applied to the upper parts of some of the streams considered in this study in past times. Branson (1967:284) also noted that *Strophitus undulatus* (=his *S. rugosus*) was "one of the most widespread species in the Spring River System." and he reported *Lampsilis ovata* and *Fusconaia flava* from numerous stations.

All the (non-extirpated) species discussed to this point may have an uncertain future in the streams where they survive, given their history of decimation in other, nearby streams. Their status could well deserve monitoring in the future.

## Species Primarily of Big Caney River and Grouse Creek but Found in Favorable Areas Elsewhere

Four species occurred widely in Big Caney River and Grouse Creek and less commonly in some other streams. It seems likely that these are species somewhat more tolerant of deteriorating environments than the preceding groups but which have, nevertheless, undergone some restriction of range, especially in streams of the Osage and Chautauqua Hills.

*Amblema plicata* Say. The Blue-Point Mussel seems an especially significant species in a paleoecological sense. Fossils in sediments of streambanks and weathered shells found in stream gravels indicate that it formerly occurred commonly in all streams surveyed except in their uppermost parts (Tables 1–4). The species still occurs at all but the uppermost stations of Big Caney River. In Grouse Creek it is absent from the uppermost station (G-1) and only weathered shells were found at the lowermost station (G-9). On Bird Creek and Middle Caney River, *A. plicata* seems presently to be restricted to the middle part of the streams, although formerly more widespread both upstream and downstream, judging by fossils and weathered shells. In Hominy Creek it has disappeared from the living fauna, although it is the most common species represented in materials from the two archeological sites (see Table 5). Fossils in streambanks and weathered shells are common at some localities on Hominy Creek. Thus, there seems to have been a change from abundance to extirpation in Hominy Creek.

*Quadrula pustulosa* (Lea). The Pimple-Back Mussel occurs commonly in Grouse Creek and Big Caney River but is rare in Middle Caney River and Bird and Salt creeks. It was absent in collections from Hominy Creek but occurred at several levels, archeologically, in Big Hawk Shelter (Table 5). Thus, it seems to be another species unable to tolerate present conditions of Hominy Creek.

*Tritogonia verrucosa* (Rafinesque). The past and present distributional

patterns of the Pistol-Grip Mussel are much like those of *Quadrula pustulosa*. It occurs commonly in the middle and lower parts of the three streams heading in Kansas. Isely (1924:Table 2), in his survey of 1910–1912, found it at two stations on Bird Creek and at one station on Salt Creek. On Salt Creek, in my survey, only weathered valves (Loc. S-7) and fossils (Loc. S-4) were found. A living specimen was found at the lowest station (B-7) on Bird Creek. On Hominy Creek only fossils were taken (Loc. H-3); however, it occurred at several levels in deposits of Big Hawk Shelter (Table 5).

*Proptera purpurata* (Lamarck). The Purple Shell Mussel was found commonly from Loc. C-6, downstream, in Big Caney River. It also occurred as a fossil, upstream, at Loc. C-4, indicating a former greater range headward. A similar situation may apply on Grouse Creek, where only weathered shells were found at upper stations. On Bird Creek fresh shells of *P. purpurata* were found only at a lower station (B-6); however, Isely (1924:Table 2) recorded it upstream at Nelagoney (my Loc. B-3). Here, again, the species seems formerly to have occurred farther upstream. It seems to have disappeared from Hominy Creek; however, fossil shells were found at Loc. H-3 and one valve was found in archeological deposits from Big Hawk Shelter. In contrast to the other streams heading in Oklahoma, *P. purpurata* was common in Salt Creek (Table 4).

Generally, in the Oklahoma streams considered, the species discussed in this section seem to have suffered much decimation. In Hominy Creek the situation is similar for all four species—former occurrence, with some species abundant, but all species now extirpated.

## Widespread Species

Eleven species seem better to have withstood environmental changes of streams in the region than have those discussed above. Most of these species occur in all streams surveyed. Exceptions are *Anodonta grandis grandis* Say, lacking in Hominy Creek, and *Truncilla donaciformis* (Lea), which seems to have a more southeastern distribution and likely never occurred in Salt or Grouse creeks. Some of these species may actually have increased in numbers and/or extended their ranges, as discussed below.

Several of these species are generally associated with (but not restricted to) upstream habitats, where they may have suffered least from any environmental changes of streams. Such species include *Uniomerus tetralasmus* (Say), *Anodonta imbecilis* Say, *Carunculina parva* (Barnes) and *Ligumia subrostrata* (Say). In contrast to the above group are *Proptera laevissima* (Lea) and *Truncilla donaciformis* (Lea), which were associated with downstream habitats. The remaining species are somewhat intermediate between the two groups noted above in regard to distribution in the streams.

In the streams heading in Kansas, *Anodonta g. grandis* occurred at all

but the uppermost stations. In Salt and Bird creeks it occurred at most stations. *Leptodea fragilis* (Rafinesque) and *Lampsilis teres* (Rafinesque) had similar distributions and habitats. In the sandier streams of the Osage and Chautauqua Hills these species extended far headward as they did also in Salt Creek, a more gravelly stream. In Big Caney River and Grouse Creek they were absent from upper stations.

*Lasmigona complanata* (Barnes) was found in the middle and lower segments of all streams surveyed. Living specimens were absent at uppermost stations but it occurred, as a fossil, at Loc. B-1 on Bird Creek.

*Quadrula quadrula* (Rafinesque) was taken in middle and lower segments of all streams surveyed except Hominy Creek. A single shell was found in archeological materials from Big Hawk Shelter. It was well preserved; possibly it had been transported from another stream by Indians, as a curiosity.

## Species That May Have Extended Their Range or Increased in Numbers

Fossil assemblages from bank deposits of Big Caney River and Grouse Creek contained a number of species that are commonly associated with *Quadrula quadrula* at the present time. However, fossils of *Q. quadrula* were found only at one locality on Grouse Creek (Loc. G-3). This suggests that *Q. quadrula* may be a hardy species, numbers of which have increased relatively recently, while some less tolerant species, such as *Fusconaia flava* and *Lampsilis radiata siliquoidea*, have been declining in numbers.

In most streams *Ligumia subrostrata*, the Pond Mussel, was common upstream but declined in numbers downstream. However in Hominy Creek, it was the dominant species at all stations except the lowermost one (H-6), suggesting that it may have achieved increased population levels in the middle part of the stream while a number of other species were becoming extinct.

It has been suggested above that some species of Big Caney River, in particular *Obliquaria reflexa* and *Truncilla truncata*, may be, at this time, increasing their range and their numbers in response to a watershed improvement program.

## Discussion of Streams and Their Faunas

From the above particular cases noted, some generalities seem derivable concerning past, present, and possibly the future of the unionaceans and their distributional patterns in the streams concerned.

1. *Big Caney River and Grouse Creek.* The watersheds of these two streams adjoin and the streams are similar habitat-wise and faunally. Big Caney River yielded 21 and Grouse Creek 18 living species (some represented by fresh shells). Grouse Creek seemingly lacks living *Obliquaria*

*reflexa, Truncilla truncata* and *T. donaciformis*. However, *O. reflexa* and *T. truncata* occurred there formerly.

Silver Creek, a lower, and the largest tributary of Grouse Creek, receives drainage at this time from an extensive hog farm located just above the confluence of Silver and Grouse creeks. Here large tracts of land have been denuded of vegetation by swine. What effect this source of silt and animal waste may have on the streams and their unionacean faunas is not known.

2. *Middle Caney River*. Only 13 species were found living in this stream; however, fossils and weathered shells indicate that at least four additional species occurred there in the past: *Fusconaia flava, Lampsilis radiata siliquoidea, Lampsilis ovata* and *Truncilla truncata*. The fauna is similar to but less diverse than that of Big Caney River. Middle Caney has a lower gradient and less discharge than Big Caney. At present it is characterized by narrow, shallow pools that extend for long distances between short riffles and that have bottoms of mud or sand. The stream is also much entrenched in most of its middle and lower course. On the favorable side, however, several small reservoirs have been constructed in the watershed in Kansas and these seem to have produced permanent flow in much of the stream. The lower part of Middle Caney River is being impounded near Copan, Washington County, Oklahoma, with construction largely completed in the summer of 1978. The relatively (for the stream) diverse assemblage at Loc. M-6 will be inundated by this impoundment.

3. *Salt Creek*. In Salt Creek only 12 living species were found. However, six additional species are known to have lived there formerly from the earlier survey of Isely (1924) and from fossil evidence. All six of these occur in streambank deposits at Loc. S-4. Thus, the fauna shows considerable change, temporally. This change may be attributable to practices of the petroleum industry. The middle and lower parts of Salt Creek flow through an area that contained large oilfields in the period 1915–1930. Pollution from oil and salt water spillage must have been common during this period. It seems likely that much or all of the unionacean fauna, except in headwaters, where oil wells were not located, was extirpated. Although there are still some oil wells in the Salt Creek watershed, these seem to be controlled to minimize escape of pollutants. Perhaps there is now underway the reestablishment of a unionacean fauna in Salt Creek, but one that differs from the original fauna. The "reestablished" fauna probably draws propagules from upstream populations that escaped extirpation. However, the original fauna may have been derived chiefly from a Pleistocene Arkansas River, a river probably more hospitable to mussels than the present sandy stream. Existence of such a former Arkansas River fauna seems likely as it is otherwise difficult to understand how mussels were disseminated to various tributaries such as Salt and Grouse creeks and the Chikaskia River. The fauna of the

middle part of Salt Creek now faces a new threat as an impoundment on the creek, near Shidler, is planned.

4. *Bird Creek.* This stream heads on the eastern flank of the Flint Hills but shortly flows into the Osage Hills. In its upper segment it once seemingly possessed a relatively rich fauna similar to that of upper Big Caney River and Grouse Creek at present. This is shown by the fossil assemblage found at Loc. B-1: *Fusconaia flava, Lasmigona complanata, Lampsilis ovata, Lampsilis radiata siliquoidea* and *Ligumia subrostrata.* Of these, only *L. subrostrata* persists at this locality at present and the first three species noted seem to have been extirpated from the entire stream. The fossil assemblage suggests that the stream was formerly larger and/or more permanent at Loc. B-1.

At Loc. B-2, at Pawhuska, weathered shells of *Amblema plicata, Fusconaia flava* and *Lampsilis r. siliquoidea* occur and at Loc. B-3, at Nelagoney, a population of *A. plicata* still survives. In his survey of 1910–1912, Isely (1924:72; Table 2) listed the following species at Nelagoney (those not found there in my survey are indicated by asterisk): *F. flava**, *A. plicata, Anodonta g. grandis, Tritogonia verrucosa**, *Proptera purpurata**, *Carunculina parva, Ligumia subrostrata* and *L. r. siliquoidea**. As in some other streams, it appears that *P. purpurata* and *T. verrucosa* formerly extended farther upstream than at present.

Further evidence of the marked change in the fauna of the Bird Creek System is produced by archeological materials from Loc. OS-135 along upper Birch Creek, a tributary. This site was excavated to a depth of 120 cm in a pre-impoundment survey related to Birch Lake (with dam on Birch Creek near Barnsdall). The present fauna of Birch Creek near OS-135 comprises *Anodonta imbecilis, Uniomerus tetralasmus* and *Ligumia subrostrata. Ligumia subrostrata* also occurs at most levels in the archeological deposits. In great contrast to the present fauna, however, was the presence of *Amblema plicata* (all levels), *Fusconaia flava* (30–70 cm), *Lampsilis r. siliquoidea* (30–110 cm) and *Lampsilis teres* (20–40 cm).

5. *Hominy Creek.* This stream is also destined to be impounded, by a dam located west of Skiatook, to produce "Skiatook Lake." Construction is in progress (1977–1979). Locs. H-5, H-4 and possibly H-3 will be inundated. A pre-impoundment archeological survey produced mussels from two sites (Locs. OS-114 and OS-138). In OS-114, Big Hawk Shelter, materials had been deposited for about 1300 years from approximately 200 to 1500 A.D. They (together with fossils and weathered shells) indicate a much different fauna formerly existed in Hominy Creek. The present fauna comprises only nine species; the archeological fauna comprises three of these plus nine additional species. Seemingly, more faunal diminution has taken place in Hominy Creek in the past century than in the preceding 2000 years.

Thus, Hominy Creek exhibits an extreme in regard to decimation of unionacean faunas in this region. What contributed to this decimation? Whatever the causes, they likely also contributed to faunal impoverishment, of a less marked nature, in other streams surveyed herein. Factors that might have been involved are:

a. *Nature of the Osage-Chautauqua Hills as related to stream bottoms and siltation.* Hominy Creek is situated almost entirely in the Osage Hills. Sandstones of these hills produce sandy floodplains, which, in turn, have been easily and deeply incised by streams in the past century and in which stream bottoms of sand and silt predominate. Such a change in nature of bottom sediments may have contributed to the demise of the former fauna of Hominy Creek, which may have contained species that were ecologically attuned to more gravelly stream bottoms and to clearer waters. In this regard, I note that streams of the Flint Hills have preserved a richer fauna than streams of the Osage/Chautauqua Hills, for example: Big versus Middle Caney River and Salt Creek versus Hominy Creek (despite pollution in Salt Creek).

b. *Intermittency.* Intermittency has been severe in streams of this region at times in this century, especially during the famed drought of the 1930's and in the 1950's (personal observations). Intermittent conditions were also noted on Hominy and Salt creeks in August, 1978. I suggest that intermittency could well have been detrimental to aquatic species requiring well oxygenated waters, related to continuous stream flow, or which, for this or other reasons, preferred a riffle habitat. This could have involved either post-larval mussels themselves or the fish hosts of their glochidia.

c. *Pollution.* It seems likely that there has been, at times in the past 60 years, pollution in Hominy Creek related to the petroleum industry. Oil wells and associated facilities are still numerous in the watershed and some are even located on the banks of the creek. Insecticides seem a possible, although undocumented, factor in causing decreases in populations and extirpation of species of mussels. However, cultivated fields are not extensive in the watershed, which is predominantly utilized for grazing.

## Localities of Collections

Each stream is designated by a letter and stations, for each stream, are numbered, beginning with 1, upstream. Distances are from approximate centers of towns mentioned. Years in which collections were made are indicated in parentheses at the end of each description.

### Bird Creek

Localities B-1 to B-5 are in Osage County, B-6 and B-7 in Tulsa County, Oklahoma.

B-1. 11.25 km NW Pawhuska on North Bird Creek. SW¼, Sec. 1, T. 26 N, R. 8 E. (1976, 1978).

B-2. W side of Pawhuska. SW¼, Sec. 4 and NW¼, Sec. 9, T. 25 N, R. 9 E. (1976-1978).

B-3. N side of Nelagoney at bridge. SE¼, NE¼, Sec. 20, T. 25 N, R. 10 E. (1976, 1977).

B-4. 0.95 km N Barnsdall below dam and above area of waterfalls. Central part, N½, SE¼, Sec. 7, T. 24 N, R. 11 E. (1977).

B-5. S side of Avant. S½, NW¼, Sec. 7, T. 23 N, R. 12 E. (1977, 1978).

B-6. 2.9 km N and 0.8 km E Skiatook, where crossed by Oklahoma Highway 11. SW¼, SW¼, Sec. 12, T. 22 N, R. 12 E. (1977, 1978).

B-7. 3.2 km ENE Sperry. NE¼, NE¼, Sec. 18, T. 21 N, R. 13 E. (1978).

## Big Caney River

C-1 and C-2 are in Elk County and C-3 to C-8 in Chautauqua County, Kansas. C-9 is in Osage County and C-10 in Washington County, Oklahoma.

C-1. 2.4 km NW Grenola in area near mouth of Shrader Branch. SE¼, SE¼, Sec. 7, T. 31 S, R. 9 E. (1976).

C-2. 3.4 km S and 0.4 km W Grenola. SE¼, SE¼, Sec. 30, T. 31 S, R. 9 E. (1976–1978).

C-3. 6.75 km S and 0.8 km W Grenola. N½, NE¼, Sec. 7, T. 32 S, R. 9 E. (1976–1978).

C-4. 1.9 km SE Cloverdale. SE¼, SE¼, Sec. 36, T. 32 S, R. 8 E. (1975–1978).

C-5. 3.45 km N and 0.4 km E Cedar Vale. S½, NE¼, Sec. 35, T. 33 S, R. 8 E. (1978).

C-6. E side of Cedar Vale from U.S. Highway 166 for 0.8 km upstream. W½, NW¼, Sec. 12, T. 34 S, R. 8 E. (1969–1978).

C-7. 3.55 km NW Hewins, immediately below Osro Falls. SW¼, SE¼, Sec. 29, T. 34 S, R. 9 E. (1974–1978).

C-8. 5.8 km WNW Elgin at Fletchers Ford, near Wilson Cemetery. NW¼, SW¼, Sec. 8, T. 35 S, R. 10 E. (1969, 1974–1978).

C-9. 0.8–1.0 km downstream from Hulah Reservoir dam. NW¼m NW¼, Sec. 12, T. 28 N, R. 11 E. (1975–1978).

C-10. 7.55 km SW Copan. NE¼, NE¼, Sec. 2, T. 27 N, R. 12 E. (1978).

## Grouse Creek

All localities are in Cowley County, Kansas.

G-1. 1.4 km S Butler–Cowley County boundary. SE¼, SE¼, Sec. 6 (oversize), T. 30 S, R. 8 E. (1976).

G-2. 8.2 km NNE Cambridge. SW¼, SE¼, Sec. 34, T. 30 S, R. 7 E. (1976–1978).

G-3. 1.8 km NNW Cambridge. S½, SW¼, Sec. 21, T. 31 S, R. 7 E. (1976–1978).

G-4. 7.4 km SSW Cambridge. NE¼, NE¼, Sec. 19, T. 32 S, R. 7 E. (1977, 1978).

G-5. 4.8 km N Dexter. SW¼, NW¼, Sec. 31, T. 32 S, R. 7 E. (1976–1978).

G-6. 1.6 km NNW Dexter. SW¼, NE¼, Sec. 12, T. 33 S, R. 6 E. (1969–1978).

G-7. 0.8 km W of mouth of Crab Creek. NW¼, SE¼, Sec. 32, T. 33 S, R. 6 E. (1976).

G-8. 2.0 km SW Vinton. NW¼, SW¼, Sec. 13, T. 34 S, R. 5 E. (1977, 1978).

G-9. 2.65 km S Silverdale, adjacent to Scout Camp Ko-Ha-Me. NW¼, SE¼, Sec. 8, T. 35 S, R. 5 E. (1974, 1975).

### Hominy Creek

All localities are in Osage County, except H-6 in Tulsa County, Oklahoma.

H-1. 11.25 km WNW Wynona on Little Hominy Creek. NE¼, Sec. 9, T. 24 N, R. 8 E. (1976, 1977).

H-2. 6.9 km N and 1.3 km E Hominy; 0.8 km ESE of junction of Big and Little Hominy creeks. SE¼, SW¼, Sec. 7, T. 23 N, R. 9 E. (1978).

H-3. 4.0 km NE Hominy. NE¼, NE¼, Sec. 32, T. 23 N, R. 9 E. (1976).

H-4. 2.6 km NW Morgans Corner. E½, NE¼, Sec. 16, T. 22 N, R. 10 E. (1976–1978).

H-5. Ca. 12 km W Skiatook. NE¼, NW¼, Sec. 28, T. 22 N, R. 11 E. (1976, 1978).

H-6. 2.0 km NE Sperry. NE corner, Sec. 13, T. 21 N, R. 12 E. (1978).

### Middle Caney River

Localities M-1 to M-4 are in Chautauqua County, Kansas; M-5 in Washington County, Oklahoma.

M-1. 1.3 km SW Belknap Cemetery. NE¼, NW¼, Sec. 30, T. 32 S, R. 10 E. (1978).

M-2. Immediately below mouth of Pool Creek, in area of Butchers Falls (on Pool Creek). NE¼, SW¼, Sec. 25, T. 33 S, R. 10 E. (1978, 1979).

M-3. S and SW of Sedan. S½, Sec. 3, T. 34 S, R. 11 E. (1977–1979).

M-4. 1.4 km NNW Peru. NW¼, NE¼, Sec. 16, T. 34 S, R. 12 E. (1977).

M-5. 2.8 km NE Niotaze. NE¼, NE¼, Sec. 21, T. 34 S, R. 13 E. (1978).

M-6. 3.2 km NW Copan. SE¼, SE¼, Sec. 7, T. 28 N, R. 13 E. (1976, 1978).

## Salt Creek

All localities are in Osage County, Oklahoma.

S-1. 1.2 km ENE Grainola. NE¼, NE¼, Sec. 3, T. 28 N, R. 6 E. (1976).

S-2. 8.0 km S Grainola and 8.0 km W Foraker. NE¼, Sec. 33, T. 28 N, R. 6 E. (1977–1979).

S-3. 2.1 km SE Shidler. SW¼, SE¼, Sec. 34, T. 27 N, R. 6 E. (1977–1979).

S-4. 4.8 km SW Shidler. NE¼, SE¼, Sec. 7, T. 26 N, R. 6 E. (1976–1979).

S-5. E part of Burbank. SW¼, SW¼, Sec. 25, T. 26 N, R. 5 E. (1976, 1977).

S-6. 1.75 km SE Remington. NW¼, NW¼, Sec. 19, T. 25 N, R. 6 E. (1976–1978).

S-7. 3.4 km NW Fairfax. SW¼, SW¼, Sec. 36, T. 25 N, R. 5 E. (1976–1978).

## Archeological Sites

OS-114 (Big Hawk Shelter) and OS-138. 11.7 km ESE of Hominy. NW¼, SE¼, Sec. 7, T. 22 N, R. 10 E. These shelters are located in a south-facing escarpment, rising above the floodplain of Hominy Creek. OS-138 is 25 m E of OS-114.

OS-135. 7.2 km ENE of Wynona on N side of Birch Creek and E side of Barnsdall-Wynona road. NE¼, SE¼, Sec. 17, T. 24 N, R. 10 E.

## Literature Cited

Branson, B. A. 1967. A partial biological survey of the Spring River drainage in Kansas, Oklahoma and Missouri. Part I, collecting sites, basic limnological data, and mollusks. Trans. Kansas Acad. Sci. 69(3–4):242–293.

Burch, J. B. 1975. Freshwater unionacean clams (Mollusca: Pelecypoda) of North America. Malacological Publications, Hamburg, Michigan, i–xviii + 204 pp.

Isely, F. B. 1924. The fresh-water mussel fauna of eastern Oklahoma. Proc. Oklahoma Acad. Sci. 4:43–118.

Liechti, P. M., and D. G. Huggins. 1977. Unionacean mussels of Kansas. Tech. Publ. State Biol. Surv. Kansas 4:17–30.

Mackie, G. L., and D. G. Huggins. 1976. Biological notes on *Eupera cubensis* (Bivalvia: Sphaeriidae) from Kansas. J. Fish. Res. Board Canada 33(7):1652–1656.

Mathews, J. J. 1961. The Osages: Children of the middle waters. Univ. Oklahoma Press, Norman, i–xx + 826 pp.

Murray, H. D., and A. B. Leonard. 1962. Handbook of unionid mussels in Kansas. Univ. Kansas Mus. Nat. Hist. Misc. Publ. 28:1–184.

Scammon, R. E. 1906. The Unionidae of Kansas, Part I. The Kansas University Sci. Bull. 3(9):279–373.

Schuster, G. A. 1979. Notes on the freshwater mussel fauna of the Verdigris River System in Kansas. Trans. Kansas Acad. Sci. 82(1):11–24.

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# Miocene Three-Toed Horse from the Salt Lake Group of Southeastern Idaho

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## ABSTRACT

A partial skull of a three-toed horse is described from the Salt Lake Group of southeastern Idaho. This specimen is referred to *Merychippus isonesus* based on the development of facial fossae, size, hypsodonty, and dental pattern. This species also is known from the Barstovian Mascall Formation of the John Day Basin of Oregon and numerous other localities in western North America. Based on the biochronology of this species, a Barstovian (medial Miocene) age is assigned to part of the Salt Lake Group of southeastern Idaho.

## INTRODUCTION

Fossil horses are common elements of Cenozoic terrestrial vertebrate-bearing deposits in North America. In the northwestern United States many kinds of three-toed horses have been recovered from rich Miocene sedimentary sequences, such as the John Day Beds and Mascall sedimentary sequence of central and eastern Oregon (e.g., Downs, 1956; Shotwell, 1968). However, little is known of contemporaneous sediments in Idaho and Utah.

The purposes of this report are to describe a well-preserved skull of a three-toed horse from the Salt Lake Group of southeastern Idaho and to discuss its biostratigraphic significance.

The following abbreviations are used in this report: AMNH, Department of Vertebrate Paleontology, American Museum of Natural History, New York; UVP, Utah Vertebrate Paleontology, Antiquities Section, Division of State History, Salt Lake City.

## RECORD OF LOCALITY

The skull was found on 14 April 1932 by Golden York, former curator at the University of Utah Museum of Earth Sciences. York's original field

notebook stated the horse was found "at Downey, Idaho." "Mammoth teeth" also were collected by York that same day "at Downey." An identification and collection label was attached to the skull in the early 1950s; however, the collection site was labeled as "½ mile west of the City Dump at Downey, Idaho."

Fieldwork by one of us (Nelson), and by others (McClellan, 1976; Yancey, 1979, written communication) has shown that deposits in the immediate vicinity of Downey (e.g., near the city dump) are Pleistocene Valley fill sediments. Moreover, McClellan (1976) collected and described what he termed the Irvingtonian (early Pleistocene) Downey Dump local fauna. The nearest exposures of the Salt Lake Group are 4.8 km southeast of Downey along Marsh Creek (Yancey, 1979, written communication).

It has been suggested that the skull might be a reworked fossil (Yancey, 1979, written communication). Downey is situated directly in the path of the late Pleistocene catastrophic flood of Lake Bonneville, and these floodwaters would have been a potential agent for moving the fossil skull to the recorded locality. However, the skull is too fragile and well preserved to have survived this type of rigorous reworking.

We suspect that the skull was collected along Marsh Creek near Downey, perhaps near Downata Hot Springs. At the same time (1932) the mammoth teeth were collected in the Pleistocene valley fill near the Downey city dump. A retired rancher living in Downey reported to Nelson that "many years ago the University of Utah collected elephant bones south of town." This locality would be in the vicinity of the city dump. When collection labels were added to the specimens in the 1950's all of the fossils (the horse skull and mammoth teeth) could have been labeled as having been collected from the area near the Downey city dump.

## Systematic Paleontology

Class MAMMALIA Linnaeus, 1758
Order PERISSODACTYLA Owen, 1848
Family EQUIDAE Gray, 1821
*Merychippus isonesus* (Cope), 1889
Figure 1, Table 1

*Holotype.* AMNH 8175, skull and associated postcranial elements (illustrated in Cope 1889, fig. 23; Cope and Matthew, 1915, plate 147, fig. 1; and Osborn, 1918, text-figs. 75, 77, plates 6, 10, 13, 17, and 42), from the Mascall Fauna, Mascall Formation, Cottonwood Creek, John Day Basin, Oregon; following Downs (1956) and Tedford et al. (pers. comm.), the age of the Mascall Fauna is early Barstovian (medial Miocene).

*Distribution of species.* Besides the Mascall Fauna, specimens referred to *M. isonesus* are known from numerous localities in western North America of Barstovian age (Stirton 1940; Downs, 1956).

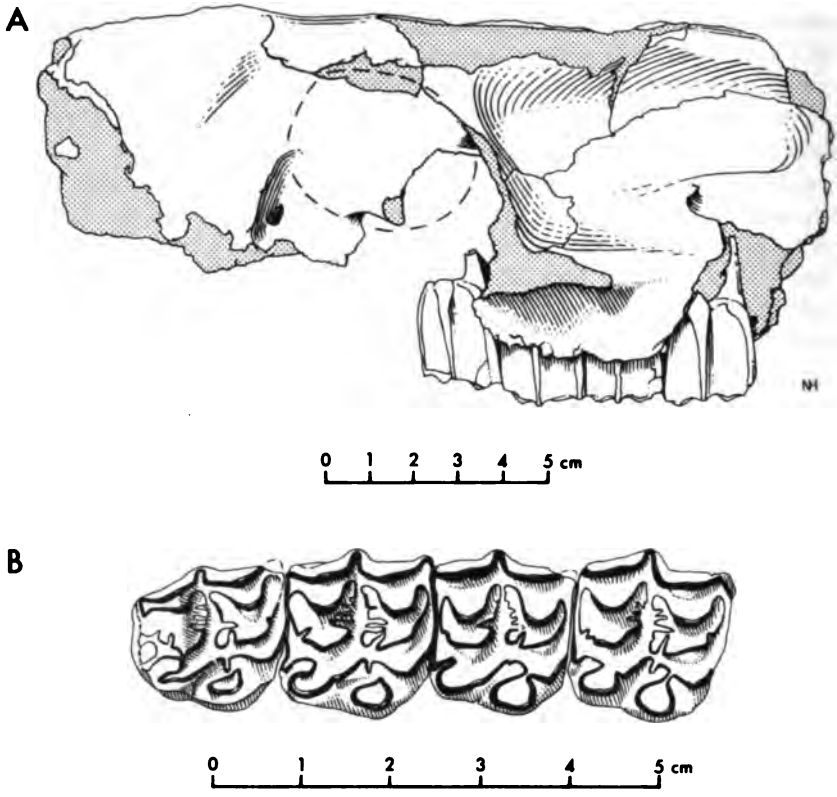


Fig. 1. *Merychippus isonesus*, UVP 042, from the Salt Lake Group, Barstovian (medial Miocene) age of southeastern Idaho. *A*, Right lateral view of skull. *B*, Occlusal view of right $P^4$–$M^3$.

*Referred specimen.* UVP 042, partial skull with right and left cheek regions and dorsal portion of skull roof, right $P^4$–$M^3$.

*Locality and horizon.* Salt Lake Group, probably from exposures along Marsh Creek and perhaps from near Downata Hot Springs (NW ¼, R. 37 E, T. 12 S), southeastern Idaho (see discussion under Record of Locality). Specimen was found on 14 April 1932 by Golden York.

*Description.* Moderately hypsodont, medium-sized, three-toed horse. On the facial region there is a relatively well developed dorsal preorbital, or lacrimal, fossa (Fig. 1). This fossa has moderately distinct dorsal and posterior borders. The anterior border is confluent with the ventral, or malar, fossa. The malar fossa is shallower than the lacrimal fossa. The posterior and ventral limits of the malar fossa are relatively well defined. The posterior border of this facial fossa complex is very close to the orbit, that is, there

Table 1. Dental measurements (mm) for *Merychippus isonesus*, UVP 042, from southeastern Idaho.

| | $P^4$ | $M^1$ | $M^2$ | $M^3$ |
|---|---|---|---|---|
| Right AP[1] | 19.4 | 16.9 | 17.9 | 18.3 |
| Right T[2] | 20.3 | 19.9 | 19.5 | 16.6 |
| Crown height[3] | 23.3 | — | — | 25.0 |

[1] Greatest anteroposterior length.
[2] Greatest transverse width.
[3] Maximum height from top of ectoloph on occlusal surface to base of enamel (not including roots).

is a very narrow preorbital bar. These facial fossae are developed on the nasal, lacrimal, jugal, and maxillary bones. Ventral to the malar fossa there is a narrow and dorsoventrally compressed facial, or malar, crest. The morphology of the facial region of UVP 042 is very similar to that of AMNH 8175, the holotype of *Merychippus isonesus* (e.g., Osborn, 1918, plate 10, fig. 4).

The cross-sectional area, size (Table 1), degree of hypsodonty, and dental pattern of the $P^4$–$M^3$ of UVP 042 is very similar to those of other specimens of *M. isonesus* for example, topotypic material in the AMNH collection and material described by Downs (1956) from the Mascall Fauna, although it should be noted that the holotype of *M. isonesus*, AMNH 8175, does not demonstrate characteristic dental pattern of this species because it represents a sub-mature individual with an occlusal surface that is just coming into wear. The cheek teeth of UVP 042 have a moderate covering of cement. The protocone is rounded and connects to the protoloph in $P^3$ and $M^1$, whereas the protocone of $M^2$ and $M^3$ is isolated and has a rudimentary anterior spur. The plicaballin consists of one moderately developed loop on $P^4$, $M^2$ and $M^3$, and is poorly developed on $M^1$. The anterior borders of the prefossettes (anterior lakes) and posterior borders of the post-fossettes (posterior lakes) are simple and have few plications. The posterior borders of the prefossettes and the anterior borders of the postfossettes are moderately plicated. The hypoconal groove is relatively deep on $P^4$, $M^2$ and $M^3$ and less well developed on $M^1$.

In summary, based on the development of facial fossae, size, degree of hypsodonty, and dental pattern, UVP 042 from the Salt Lake Group of southeastern Idaho should be referred to the three-toed horse species *Merychippus isonesus*.

## Discussion

*Taxonomy*. *Merychippus isonesus* was described and named by Cope (1889) based on a well-preserved specimen (the holotype, AMNH 8175) and

topotypic material from Cottonwood Creek in the John Day Basin of Oregon. *M. isonesus* seems to have been relatively widespread in western North America during the Barstovian, as specimens from numerous localities have been referred to this species (Stirton, 1940; Downs, 1956). Downs (1956), in his study of the Mascall Fauna of eastern Oregon, synonymized *M. isonesus* with the earlier-named, *M. seversus* Cope (1879). At least two facial morphotypes were illustrated for *M. seversus* by Downs (1956, compare fig. 24, p. 269; fig. 26, p. 279; and fig 27, p. 280). It is clear from the illustration that one facial morphotype (fig. 26 and possibly fig. 27) is similar to the holotype of *M. isonesus* and UVP 042. The name *M. isonesus* is used in the present report because: 1) there is confusion surrounding the type specimen of *M. seversus* (it might be a *nomen vanum*, Downs, 1956, p. 256); 2) it is probable that the two facial morphotypes are represented in the Mascall Fauna; 3) *M. isonesus* has been in common usage for nearly a century.

*Biostratigraphy.* Fossil mammals previously have not been reported from the Salt Lake Group in southeastern Idaho. The well preserved skull, UVP 042, described in this report demonstrates diagnostic facial and dental characters of the species *Merychippus isonesus*, which is common in Barstovian (medial Miocene) deposits in western North America. Therefore, a similar Barstovian age is assigned to part of the Salt Lake Group in southeastern Idaho. The nearest exposures of the Salt Lake Group that also contain a Barstovian mammalian fauna have been reported from Box Elder County, Utah (McClellan, 1976), more than 200 km southwest of Downey. Most other reports of vertebrates (mostly fish) suggest a late Miocene to Pliocene age for much of the Salt Lake Group in northern Utah and southeastern Idaho (McClellan, 1977). The Marsh Creek locality might represent sediments near the base of the Salt Lake Group in southeastern Idaho and northeastern Utah (in the strict sense of Nelson 1971, 1973, 1976; it does not include the Norwood Tuff and correlatives or the tuffaceous sediments of Jordan Narrows and the southern Wasatch Mountains).

## ACKNOWLEDGMENTS

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at Fort Hays State University and from DINOLAB, Salt Lake City, Utah. University of Florida Contribution to Vertebrate Paleontology number 182.

## LITERATURE CITED

Cope, E. D. 1879. On some characters of the Miocene fauna of Oregon. Amer. Philos. Soc. Proc. 18:63–78.

Cope, E. D. 1889. A review of the North American species of *Hippotherium*. Amer. Philos. Soc. Proc. 26:429–458.

Cope, E. D., and W. D. Matthew. 1915. Hitherto unpublished plates of Tertiary Mammalia and Vertebrata. Prepared under the direction of Edward Drinker Cope for the U.S. Geological Survey of the Territories with description of plates by William Diller Matthew. Published by the U.S. Geol. Survey and the Am. Mus. Nat. Hist., Monograph ser. no. 2, 154 pls.

Downs, T. 1956. The Mascall Fauna from the Miocene of Idaho. Univ. California Dept. Geol. Sci. Pub. 31:199–354.

McClellan, P. H. 1976. New evidence for the age of the Cenozoic Salt Lake beds in the northeastern Great Basin (abs.). Soc. Econ. Paleont. Mineral. Pacific Sect. 51st. Ann. Meet. Prog. Abst.

McClellan, P. H. 1977. Paleontology and paleoecoloty of Neogene freshwater fishes from the Salt Lake beds, northern Utah. Unpubl. M.S. thesis, Univ. of California, Berkeley, 243 pp.

Nelson, M. E. 1971. Stratigraphy and paleontology of Norwood Tuff and Fowkes Formation, northeastern Utah and southwestern Wyoming. Unpubl. Ph.D. dissert., Univ. Utah, Salt Lake City, 169 pp.

Nelson, M. E. 1973. Age and stratigraphic relations of the Fowkes Formation, Eocene, of southwestern Wyoming and northeastern Utah. Contrib. Geol. 12(1):27–31.

Nelson, M. E. 1976. A new Oligocene faunule from northeastern Utah. Trans. Kansas Acad. Sci. 79(1–2):7–13.

Osborn, H. F. 1918. Equidae of the Oligocene, Miocene, and Pliocene of North America. Iconographic type revision. Mem. Am. Mus. Nat. Hist., new ser. 2:1–326.

Shotwell, J. A. 1968. Miocene mammals of southeastern Oregon. Univ. Oregon Mus. Nat. Hist. Bull. 14:1–67.

Stirton, R. A. 1940. Phylogeny of North American Equidae. Univ. California Dept. Geol. Sci. Pub. 25:165–198.

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83(1), 1980, pp. 26–32

# The Identity of *Centrolenella grandisonae* Cochran and Goin (Anura: Centrolenidae)

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ABSTRACT

The name *Centrolenella grandisonae* was misapplied by Lynch and Duellman (1973); the name is now associated with a red-spotted species on the Pacific versant of Colombia and Ecuador. A new name, *Centrolenella lynchi*, is proposed for the species that was erroneously called *Centrolenella grandisonae*.

The richness of the centrolenid frog fauna on the Pacific slopes of Colombia and Ecuador is only now being appreciated. Lynch and Duellman (1973) recorded five species from the cloud forests on the Pacific slopes of Ecuador, but fieldwork in 1974–1979 has more than doubled that number and has resulted in the discovery of additional species in Colombia.

Lynch and Duellman (1973) associated five specimens of a spotted *Centrolenella* from Tandapi, Ecuador, and two from Santa Leticia, Colombia, with *Centrolenella grandisonae*, a species described by Cochran and Goin (1970) on the basis of a single specimen from Pueblo Rico, Colombia. Lynch and Duellman (1973) noted that the holotype of *C. grandisonae* differed from the specimens that they assigned to that species by being slightly larger and by having prevomerine teeth.

During the past five years numerous specimens of a distinctive red-spotted *Centrolenella* have been collected in Ecuador and Colombia. Study of these specimens reveals that they are representatives of the species named *C. grandisonae* by Cochran and Goin. In the following redescription of the species, the sequence in the numbered diagnosis and the terminology follow Lynch and Duellman (1973).

## *Centrolenella grandisonae* Cochran and Goin

*Centrolenella grandisonae* Cochran and Goin, 1970:513 [Holotype. BMNH 1910.7.11.68 from Pueblo Rico, Departamento de Caldas, Colombia].

*Diagnosis.* 1) prevomerine teeth 0–4; 2) bones pale green; 3) parietal peritoneum white; visceral peritoneum clear; 4) color in life green with small

red spots; in preservative, lavender with white spots; 5) webbing between outer fingers III 2¼—2 IV; 6) webbing on foot I 1½—2 II 1½—2 III 1½—2¼ IV 2¼—1½ V; 7) snout round in dorsal view, rounded dorsally and abruptly inclined in profile; 8) dorsal skin pustular; 9) arms and legs lacking dermal folds; 10) humeral spine present in males; 11) lower two-thirds of tympanum visible, directed posterolaterally with dorsal inclination.

The presence of red spots on a granular dorsum immediately distinguishes *C. grandisonae* from other known species of *Centrolenella*. In skin texture, *C. grandisonae* is most like *C. megacheira*, which has black spots on the dorsum and lacks humeral spines in the males. Other *Centrolenella* that have white spots on a lavender dorsum in preservative differ from *C. grandisonae* by having smooth or shagreened skin on the dorsum.

*Description.* Adults moderately large; snout-vent length 25.1–29.3 mm ($\bar{x}$ = 27.2, $n$ = 44) in males, 28.9–30.7 mm ($\bar{x}$ = 29.8, $n$ = 4) in females; head wider than body; width of head 32.6–36.8 percent ($\bar{x}$ = 34.3, $n$ = 48) of snout-vent length. Snout short, high, round in dorsal view, in profile rounded anterior to nostrils and abruptly sloping ventrally to margin of lip; canthus round; loreal region shallowly concave; lips rounded; nostrils about five-eights distance from eye to tip of snout, barely protuberant laterally; internarial area barely depressed. Eye large, protuberant, directed anterolaterally. Upper one-third of tympanum covered by pustular supratympanic fold; tympanic annulus distinct ventrally; tympanum directed posterolaterally with moderate dorsal inclination. Prevomerine teeth 0–0—3–4 (total teeth 0–7, $\bar{x}$ = 2.63, $n$ = 44, in males; 0–6, $\bar{x}$ = 4.5, $n$ = 4, in females); dentigerous processes of prevomers transversely elliptical and broadly separated medially, between small ovoid choanae; tongue boradly separated medially, between small ovoid choanae; tongue broadly cordiform, shallowly notched posteriorly, barely free behind; vocal slits extending from midlateral base of tongue to angles of jaws; vocal sac single, median, subgular.

Humeral spine long, pointed, essentially parallel to axis of humerus, tip enclosed by skin of upper arm; forearm moderately robust; ulnar fold and tubercles absent; first finger slightly shorter than second; fourth finger much longer than second; lateral fringes on fingers; webbing absent between first and second fingers; webbing formula for other fingers II (2–2½)—(3¼–3½ III (2–2½)—(2–2¼) IV; webbing emarginate; discs broad, rounded; subarticular tubercles small, round, simple; supernumerary tubercles absent; palmar tubercle low, bifid; nuptial excrescences absent. Hind limbs slender; length of tibia 54.0–62.3 percent ($\bar{x}$ = 57.6, $n$ = 48) of snout-vent length; tarsal folds and tubercles absent; inner metatarsal tubercle ovoid, flat; outer metatarsal tubercle small, round; subarticular tubercles small, round; supernumerary tubercles absent; toes about three-fourths webbed; webbing formula I (1–1¾)—(2–2¼) II (1–1½)—(2–2½) III (1–1½)—(2–2¼) IV (2–2¼)—(1–1½) V; discs round, slightly smaller than those on fingers.

Fig. 1. *Centrolenella grandisonae*, KU 164670, ♀, 30.7 mm snout-vent length.

Skin on dorsum finely pustular; skin on belly and proximal posteroventral surfaces of thighs coarsely granular; skin on other surfaces smooth. Anal opening directed posteriorly below broad dermal flap at upper level of thighs; numerous small round tubercles below anal opening; pair of large, flat tubercles on proximal ventral surfaces of thighs.

Color in preservative: dorsal surfaces of head, body, forearm, thigh, shank, and tarsus lavender; upper lip, upper arm, hands, feet, flanks, and venter cream. Small round pink to white spots on head (including eyelids), dorsum of body, and usually on shanks (3–21 spots on head and body, $\bar{x}$ = 9.6, $n$ = 48; 0–4 spots on each shank, $\bar{x}$ = 1.53, $n$ = 96).

Color in life: dorsum green with small bright red spots; parietal peritoneum creamy white; visceral peritoneum clear; heart not visible; vocal sac and bones green iris silvery white with black flecks (Fig. 1).

*Distribution. Centrolenella grandisonae* is widely distributed in cloud forest on the Pacific slopes of the Cordillera Occidental from Departamento de Calda, Colombia, to Provincia de Pichincha, Ecuador. It has a known elevational distribution from 1140 to 1850 m.

Specimens examined: COLOMBIA: *Caldas:* Pueblo Rico, 1540 m, BMNH 1910.7.11.68. *Valle:* Río Calima, 1.5 km W Lago Calima, 1230 m, KU 169670–74. ECUADOR: *Carchi:* Maldonado, 1410 m, KU 178168–69. *Pichincha:* 4 km NE Dos Ríos, 1140 m, AMNH 95477, KU 164670–85; 25.7 km ENE La Palma (Chiriboga Road), 1820 m, MCZ 93587; 3.5 km NE

Mindo, 1540 m, AMNH 95474–76, KU 164686–90; 2 km E Tandapi, 1550 m, MCZ 93023–26, 97848–51, USNM 211211; 1 km SW Tandayapa, 1640 m, MCZ 97847, USNM 211214; 2.9 km SW Tandayapa (Mindo Road), 1820 m, USNM 211212–13; 5.1 km SE Tandayapa (Nono Road), 1850 m, USNM 211215.

*Remarks.* Most males were calling from the upper sides of leaves (up to 3 m) above streams varying from narrow trickles to 2 m wide. The call is a single, loud, piercing "peep."

The proper allocation of the name *Centrolenella grandisonae* leaves the taxon to which that name was applied by Lynch and Duellman (1973) without a specific name.

*Centrolenella lynchi* new species

*Holotype.* KU 164691, an adult male, from a stream 4 km northeast (by road) of Dos Ríos, Provincia de Pichincha, Ecuador, 1140 m (00°21'S, 78°54'W), one of a series collected on 2 April 1975 by William E. Duellman and Alan H. Savitzky.

*Paratopotypes.* KU 164692–99, collected with the holotype; KU 164700 obtained on 7 May 1975 by William E. Duellman.

*Diagnosis.* 1) prevomerine teeth absent; 2) bones pale green; 3) parietal peritoneum white; visceral peritoneum clear; 4) color in life green with minute yellowish white flecks and small black spots; in preservative, lavender with small dark spots and white flecks; 5) webbing between outer fingers III 2—2 IV; 6) webbing on foot I 1—2 II 1—2 III 1—2 IV 2—1 V; 7) snout truncate in dorsal view, round in profile; 8) dorsal skin shagreened with fine spicules; 9) low ulnar fold on forearm; 10) humeral spine present in males.

Two other Ecuadorian species are lavender in preservative with dark spots and white flecks on the dorsum. Of these, *C. pipilata* differs from *C. lynchi* by having tarsal folds and incised webbing; *C. peristicta* is nearly identical to *C. lynchi* in coloration but has more webbing on the hand—III 2—1½ IV. Both species are smaller than *C. lynchi*; males of *C. pipilata* have snout-vent lengths of 19.5–22.9 mm ($\bar{x}$ = 21.5, $n$ = 10) and those of *C. peristicta* are 18.7–20.6 mm ($\bar{x}$ = 19.7, $n$ = 2).

*Description.* Adults moderate in size; snout-vent length 23.5–26.4 mm ($\bar{x}$ = 24.7, $n$ = 9) in males, 24.9 mm in single female; head as wide as body, much wider than long; width of head 33.6–36.7 percent ($\bar{x}$ = 34.9, $n$ = 10) of snout-vent length. Snout short, high truncate in dorsal view, round in profile; canthus round; loreal region barely concave; lips round; nostrils about two-thirds distance from eye to tip of snout, slightly protuberant anterolaterally; internarial area noticeably depressed. Eye moderately large, protuberant, directed anterolaterally. Upper one-third of tympanum covered by supratympanic fold; tympanic annulus distinct ventrally; tympanum directed posterolaterally with posterodorsal inclination. Prevomerine dentig-

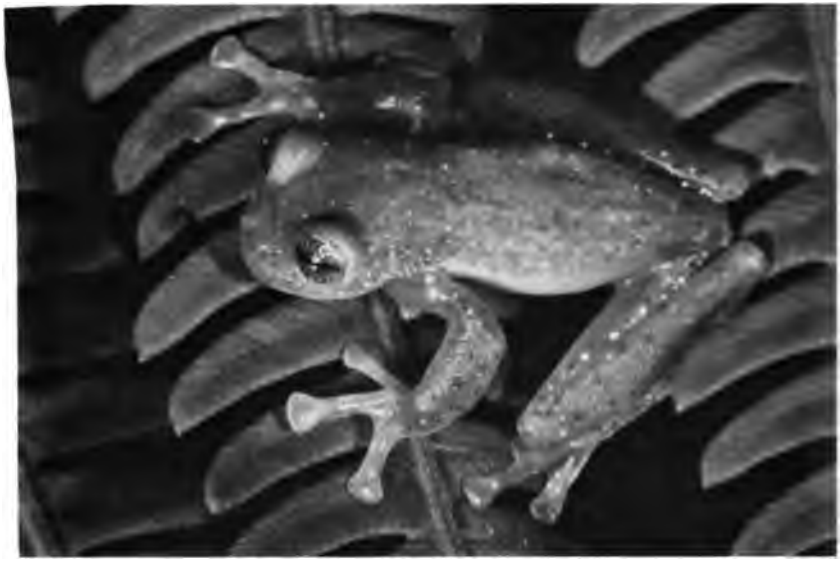

Fig. 2. *Centrolenella lynchi*, KU 164691, ♂, 25.3 mm snout-vent length.

erous processes and teeth absent; choanae longitudinally ovoid; tongue broadly cordiform, shallowly notched behind, free prosteriorly for about one-third of its length; vocal slits extending from midlateral base of tongue to angles of jaws; vocal sac single, median, subgular.

Humeral spine, short, pointed, at right angle to humerus, tip enclosed by skin of upper arm; forearm robust, bearing low ulnar fold; first finger slightly shorter than second; fourth finger much longer than second; lateral fringes on fingers; webbing absent between first and second fingers; webbing formula for other fingers II 2—3 III (2–2½)—2 IV; webbing emarginate; discs broad, rounded; subarticular tubercles moderately large, round, simple; supernumerary tubercles absent; palmar tubercle low, ovoid, simple; nuptial excrescences absent. Hind limbs moderately slender; length of tibia 57.1–62.1 percent ($\bar{x}$ = 59.8, $n$ = 10) of snout-vent length; tarsal folds and tubercles absent; inner metatarsal tubercle rounded, ovoid; outer metatarsal tubercle small, conical; subarticular tubercles small, round; supernumerary tubercles minute, present on proximal segments; toes about webbed; webbing formula I 1—2 II 1—2 III 1—2 IV 2—1 V; discs round, slightly smaller that those on fingers.

Skin on dorsum shagreened with scattered minute spicules, especially prominent in temporal region and along posterior margin of jaw; skin on belly and proximal posteroventral surfaces of thighs coarsely granular; skin on other surfaces smooth. Anal opening directed posteriorly below short

anal sheath at upper level of thighs; numerous small, round tubercles below anus; pair of large, flat tubercles on proximal ventral surfaces of thighs.

Color in preservative: dorsal surfaces of head, body, and limbs, exclusive of digits, lavender with many minute white flecks and more numerous, larger dark lavender spots; flanks, venter, and hidden surfaces of limbs cream.

Color in life: dorsum dull green with minute yellowish white and black flecks; tips of digits yellow; parietal peritoneum creamy white; visceral peritoneum clear; heart not visible; bones green; iris bronze with black reticulations (Fig. 2).

*Variation.* Fourteen males and one female from Tandapi, 1460 m, Provincia de Pichincha, Ecuador, are like the type series in coloration, but the spicules in the skin are less conspicuous. Also there is slightly less webbing on the hand in some individuals; in six males the webbing formula is II 2—3½ III 2—2 IV, and in one it is II 2—3½ III 2½—2 IV, whereas in the others the webbing is the same as that in the type series.

The 14 males from Tandapi have snout-vent lengths of 23.3–26.0 mm ($\bar{x}$ = 24.8) and the one female, 24.8 mm. The samples from Tandapi and from the type locality are significantly different ($P < 0.01$; student-$t$) in the ratios of head width, tibia length, and foot length to snout-vent length (SVL); in each case the ratios are smaller in the sample from Tandapi, indicating that frogs from there have proportionately longer bodies than do those at the type locality. In the following list of data, the topotypes ($n$ = 9) are followed by the data for the sample from Tandapi ($n$ = 14); the range is followed in parentheses by the mean and one standard deviation: head width/SVL .336–.367 (.350 ± .010), .314–.349 (.334 ± .009); tibia length/SVL .571–.621 (.599 ± .018), .549–.609 (.571 ± .016); foot length/SVL .521–.563 (.540 ± .015), .481–.514 (.499 ± .010).

*Distribution.* This species is known from elevations of 1140–1500 m on the Pacific slopes of the Cordillera Occidental in Ecuador, where it inhabits cloud forest.

Specimens examined: ECUADOR: *Pichincha*: 4 km NE Dos Ríos, 1140 m, KU 164691–700; 14.4 km ENE La Palma (Chiriboga Road), 1380 m, MCZ 91455; Tandapi, 1460 m, KU 118036, 118047–50, 178095–105; 2.1 km E Tandapi, 1500 m, MCZ 93313–14, 95742.

*Remarks.* Males were calling from the upper sides of leaves of trees and bushed overhanging streams; at the type locality, they were 2.5–4 m above the water. At that stream, *Centrolenella prosoblepon* and *C. valerioi* also were calling, and *C. grandisonae* was calling from vegetation along a small tributary.

Lynch and Duellman (1973) referred two specimens (KU 144129–30) from Santa Leticia, 2000 m, Departamento de Cauca, Colombia, to *C. grandisonae* (=*C. lynchi*). I am not convinced that those specimens are *C. lynchi* and at present do not assign them to any known species.

*Etymology*. I take pleasure in associating this frog with John D. Lynch, who collected the first specimens in 1968 and joined me in perpetrating the error of assignment of *C. grandisonae* in 1973.

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## Literature Cited

Cochran, D. M., and C. J. Goin. 1970. Frogs of Colombia. Bull. U.S. Natl. Mus. 288:1–655.

Lynch, J. D., and W. E. Duellman. 1973. A review of the centrolenid frogs of Ecuador, with descriptions of new species. Occas. Pap. Mus. Nat. Hist. Univ. Kansas 16:1–66.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
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# Decomposition of Litter in Kansas Bluestem Prairie[1]

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ABSTRACT

From 1 April to 26 August 1978, about 45 percent of the aboveground standing dead plant material and litter disappeared in ungrazed bluestem prairie on Konza Prairie Research Natural Area, Geary County, Kansas, USA. In plots trampled on April 1 to compact the material close to the soil surface about 55 percent of the material decomposed. The results are based on 10 replications in native prairie on deep, productive, silty-clay loam at two sites, 1 and 5 years since burning.

The amount of decomposition of aboveground standing dead plant material and litter was studied on the southern part of Konza Prairie Research Natural Area, 14 km south of Manhattan, Kansas at the north edge of Geary County. The study was begun in the spring of 1978 on two sites, one last burned in the spring of 1973, the other last burned in the spring of 1977, or 5 and 1 years since burning. Both were on lower slopes with Tully silty-clay loam, 4 to 8 percent slope. This soil is deep, not rocky, moderately permeable, and representative of the productive bluestem prairie soils that support grasses 2 meters tall in good years. The 108-year median precipitation at nearby Manhattan is 779 mm.

In March, 1978, 50 plots, each 0.5 by 1.5 meters, were marked in a block in each of the two sites and two treatments were instituted: trampled and control. All plots were randomly selected. Ten plots in each site were sampled on April 1 to obtain the initial weight of above ground organic matter. At the same time the standing dead plant material was compacted on 20 plots at each site by breaking stems by hand and by walking on the plots until the material lay close to the soil surface.

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Table 1. Oven-dry weights (g/m²) and least significant differences (LSD) of standing dead plant material and litter at three dates on areas 1 year and 5 years since burning. Values in parentheses are percent loss in weight from the initial weights on 1 April. Averages of 10 plots, each 0.1 m².

| Date of sampling | 1 year since burning | | 5 years since burning | |
|---|---|---|---|---|
| | Control | Trampled | Control | Trampled |
| 1 April | 680 | | 950 a* | |
| 5, 7 June | 503 a (26) | 382 ab (44) | 884 a (7) | 591 b (38) |
| 26 August | 383 ab (44) | 334 b (51) | 507 b (47) | 332 (65) |
| | LSD, 5% | 102 | LSD, 5% | 170 |
| | 1% | 136 | 1% | 228 |

* Values for each of the two treatments followed by the same letter are not significantly different at the 5 percent level.

Sampling was done in 20 by 50 cm (0.1 m²) plots by clipping as close to the soil surface as feasible, placing the standing dead and litter in a paper sack, oven-drying at 60°C, and weighing. Production of the 1978 season was removed to the extent it could be distinguished. Separation was complete in June, but a small amount, probably insignificant to the current year's growth, may not have been removed in August. Approximately 2 and 4 months after the first sampling, 10 control plots and 10 trampled plots were sampled in each site at each date. Vacuuming was not employed, but care was taken to pick up as much organic matter on the soil surface as possible in these small plots.

A little less than half the aboveground dead organic matter disappeared in the four months from April through August (Table 1). Trampling caused a significant increase in the amount decomposed. The increase is likely to have resulted from slower drying and perhaps from warmer temperatures than in the untrampled material. The few other studies that provide information on rate of decomposition in bluestem or tallgrass prairie also found that about half of the material disappeared during the growing season (Hadley and Kieckhefer, 1973; Kucera et al., 1967).

The increased rate of decomposition resulting from trampling implies that compaction by snow speeds up decomposition. This should help compensate for the shorter decomposition season in the northern than in the southern part of the bluestem prairie, and is a factor in the variation in amount of aboveground dead organic matter from year to year.

The trampling effect also implies that trampling by livestock would increase decomposition, but this effect would be complicated by changes in the amount of material entering the standing dead plant material and litter compartments of the ecosystem (Sims and Singh, 1978).

## LITERATURE CITED

Hadley, E. B., and B. J. Kieckhefer. 1963. Productivity of two prairie grasses in relation to fire frequency. Ecology 44(2):389–395.

Kucera, C. L., Roger C. Dahlman, and Melvin R. Koelling. 1967. Total net productivity and turnover on an energy basis for tallgrass prairie. Ecology 48(4):536–541.

Sims, P. L., and J. S. Singh. 1978. The structure and function of ten western North American grasslands IV. Compartmental transfers and energy flow within the ecosystem. Journal of Ecology 66(3):983–1009.

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# Nutritive Value of Three Kansas Hays for the Mature Horse[1]

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## Abstract

Six digestion trials were conducted to determine the value of three Kansas hays (brome, fescue, and prairie) as feed for the mature horse. Digestibility coefficients were calculated for dry matter, crude protein, ether extract, crude fiber, nitrogen-free extract, cell-wall constituents, acid-detergent fiber, cell solubles, and hemicellulose. Nitrogen, calcium, and phosphorous balances were measured simultaneously.

The hays tested were found to be generally low in energy, calcium, protein and phosphorus. Brome and fescue had adequate digestible crude protein, but the animals were in negative nitrogen balance. The hays had 24–45% nonprotein nitrogen that was unavailable because of the limited energy intake. Brome and prairie hays were nearly equivalent in value; of the hays studied, fescue was the least valuable nutritionally.

Supplementing the hay ration with a calcium source and at least 0.5 kg of grain daily is suggested to meet the nutritional requirements of a mature, idle horse.

Information on the digestibility of the proximate nutritients from various forages by horses, compared with that available for ruminants is scarce. Many trials on alfalfa and timothy hays as roughage for horses have been conducted, but more information is needed concerning other roughages. Fonnesbeck et al. (1967) determined the digestibility of several hays including brome, alfalfa, fescue, red clover, timothy, and canarygrass. They compared the values with those established by the National Research Council (NRC, 1958), finding crude fiber digestibilities of brome, alfalfa, fescue, and

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timothy hays to be higher and nitrogen-free extract (NFE) digestion values of brome, fescue, and timothy hays lower than published NRC values. The legume hays were more digestible than the grasses. Fonnesbeck (1968, 1969) found cell wall constituents of brome to be more digestible than those of other hays studied; brome had more digestible acid detergent fiber (ADF). The apparent digestibilities for hemicellulose, cellulose, and lignin were close to the estimated true digestibility coefficients (Fonnesbeck, 1969).

In this study we determined the digestibility coefficients and nutritive values of Kansas grown brome, fescue, and prairie hays for idle, mature horses.

## Materials and Methods

Three grade geldings, 3 or 4 years old weighing 429 to 544 kg, were fed three hays, prairie, brome, and fescue in six digestion trials by using a completely randomized factorial experimental design. Hays were harvested in mid-bloom from University Experimental farms. The animals were adjusted to each hay for one week in a drylot. They were weighed, then placed in metabolism stalls (similar to those of Stillions and Nelson, 1968) for one week. A 2-day adjustment period was allowed before a 5-day collection period. Horses were weighed at the end of each collection period and allowed a week of rest between trials. Each day the horses were fed hays at 2% of body weight (half fed in the morning and half in the evening), an amount recommended by Pfander and Bradley (1975), Schryver and Hintz (1975), Ensminger (1977), and Evans et al. (1977) for maintaining a mature idle horse. The hay refused was weighed and subtracted from the amount fed to determine intake. Each hay was fed in duplicate trials. The animals were watered four times daily and exercised for 15 minutes each day to prevent stiffness.

Total urine collections were acidified with dilute sulfuric acid to prevent ammonia loss. Total volume was measured daily and a 10% sample was stored in a refrigerator at 4°C. At the end of each trial, urine samples were combined and thoroughly mixed so that a single sample for each horse could be taken for nitrogen, phosphorus, and calcium analysis.

Feces were collected every 12 hours for 5 days. Samples, after being dried at 40°C in a draft oven and ground in a Cristy Norris mill, were analyzed for proximate components, calcium, phosphorus, and gross energy (A.O.A.C., 1975). Van Soest fiber components (neutral and acid detergent fibers) were determined by the method of Goering and Van Soest (1970) as modified by Robertson and Van Soest (1977). The hays were further analyzed for the nitrogen components of acid detergent nitrogen, hot-water insoluble nitrogen (Goering and Van Soest, 1970), ammonia nitrogen (A.O.A.C., 1975), and urease nitrogen (Conway, 1963) to calculate the estimated true-protein digestibility.

Table 1. Chemical analysis of hays fed to horses.

| Hay | Prairie | Brome | Fescue |
|---|---|---|---|
| Proximate components, % | | | |
| Dry matter | 89.72 | 90.00 | 88.89 |
| Crude protein | 4.67 | 9.44 | 7.75 |
| Crude fiber | 29.25 | 31.68 | 34.51 |
| Nitrogen-free extract | 45.60 | 40.44 | 33.00 |
| Ether extract | 1.88 | 1.90 | 2.82 |
| Ash | 8.32 | 7.56 | 10.81 |
| Van Soest components, % | | | |
| Cell solubles | 30.57 | 29.20 | 24.78 |
| Neutral detergent fiber | 69.43 | 70.80 | 75.22 |
| Acid detergent fiber | 45.66 | 39.97 | 44.49 |
| Hemicellulose | 23.77 | 30.83 | 30.73 |
| Gross energy, kcal/gm | 3.92 | 4.00 | 3.92 |
| Calcium, % | 0.322 | 0.230 | 0.225 |
| Phosphorus, % | 0.095 | 0.246 | 0.290 |

Digestibility coefficients were calculated for dry matter, crude protein, ether extract, crude fiber, nitrogen-free extract, energy, cell-wall constituents, acid detergent fiber, cell solubles, and hemicellulose. Total digestible nutrients (TDN) values were calculated from these coefficients. Nitrogen, calcium, and phosphorus balances were estimated by standard procedures.

Two-way analysis of variance (Barr et al., 1976), Duncan's new multiple range test (Steel and Torrie, 1960), and Fisher's least significant difference (LSD) test (Snedecor and Cochran, 1967) were used to analyze the data.

## Results and Discussion

Composition of the hays is given in Table 1; digestion coefficients, in Table 2; and calculated digestible nutrient contents, in Table 3.

The experimental hays used were of slightly lower nutritive value than average values summarized by the National Research Council (NRC, 1978). All composition values for prairie hay (Table 1) were lower than composite values for native, midwest, dried plants (1-03-191). There were no comparative values for the Van Soest analyses given by NRC. The brome values were lower than the NRC values for late-bloom brome hay (1-00-888) except for cell wall, acid detergent fiber, calcium, and phosphorus, which were similar. The pattern for fescue hay was similar to that for NRC analyses (1-01-912) except that our Van Soest components were higher and crude fiber values were similar.

Average daily dry matter consumption for all hays was above or within the recommended daily feed allowances (NRC, 1978). The daily dry matter

Table 2. Digestibility coefficients and balance values of three native hays fed to horses.

| Item | Prairie | Brome | Fescue | *P* | SE |
|---|---|---|---|---|---|
| Dry matter, % | 50.13 | 52.19 | 41.52*** | .0363 | 4.07 |
| Crude protein, %****4 | 32.71*** | 64.51 | 63.75 | .0042 | 11.52 |
| Crude fiber, %**2 | 53.07* | 47.54 | 40.32* | .0222 | 5.58 |
| Nitrogen-free extract, %** | 51.33 | 55.25 | 38.01*** | .0158 | 4.12 |
| Ether extract, % | 24.38 | 1.32 | 34.82 | .1224 | 28.69 |
| Cell wall constituents, %** | 49.69 | 52.62 | 41.87*** | .0401 | 5.07 |
| Cell solubles, % | 50.40 | 51.14 | 40.45*** | .1947 | 3.07 |
| Acid detergent fiber, %** | 47.32 | 41.54 | 30.94*** | .0449 | 5.88 |
| Hemicellulose, %** | 54.24 | 66.84*** | 57.68 | .0139 | 5.41 |
| Nitrogen balance, g/day | −11.72 | −5.19 | −17.87 | .4281 | 16.80 |
| Calcium balance, g/day** | 9.40 | 2.89 | −0.43 | .0173 | 7.68 |
| Phosphorus balance, g/day | −1.95* | 2.75* | 0.06 | .0740 | 3.13 |

* Significant at .05 by Duncan's test, one column being different from the other one starred but not different from the one not starred.

** Significant at the .05 level by analysis of variance.

*** Significant at .05 by Duncan's test, meaning that that column is different from either of the others.

**** Significant at the .01 level by analysis of variance.

intakes (kg/day) for prairie, brome, and fescue hays were 7.72, 8.31, and 7.80, respectively.

Digestibility coefficients (Table 2) were similar for prairie and brome hays but lower ($P < .01$) for fescue with respect to dry matter, nitrogen-free extract, cell-wall constituents, cell solubles, and acid-detergent fiber. Hemicellulose in brome was higher in digestibility ($P < .05$) than fescue or prairie hay. The digestible crude protein of prairie hay was significantly lower ($P < .005$) than that of either brome or fescue; prairie hay had a lower crude protein content initially (Table 1). We calculated digestibility coefficients for ether extract, although crude fat has questionable value for horses (Fonnesbeck et al., 1967); even so, the digestibility variance was too large and actual ether-extract values too low to be of any consequence. Calculations

Table 3. Digestible nutrient content of three native hays for the horse.

| Item | Prairie | Brome | Fescue |
|---|---|---|---|
| TDN, % | 41.52 | 43.70 | 34.14 |
| Digestible crude protein, % | 1.53 | 6.09 | 4.94 |
| Digestible ether extract, % | 0.46 | 0.03 | 0.98 |
| Digestible crude fiber, % | 15.52 | 15.06 | 13.91 |
| Digestible NFE, % | 23.41 | 22.34 | 12.55 |
| Digestible dry matter, % | 44.98 | 47.50 | 36.91 |

Table 4. Partition of nitrogenous components of prairie, brome, and fescue hays.[1]

| Item | Hay | | |
|---|---|---|---|
| | Prairie | Brome | Fescue |
| Kjeldahl N, % | 0.832 | 1.656 | 1.393 |
| Acid detergent N, % | 0.170 | 0.115 | 0.090 |
| Hot water insoluble N, % | 0.635 | 0.915 | 0.945 |
| Ammonia N, % | 0.0045 | 0.0032 | 0.0014 |
| Urease N, % | 0.0089 | 0.0160 | 0.0121 |
| Unidentified N, % | 0.0136 | 0.6068 | 0.3445 |

[1] Dry matter basis.

of the digestible nutrient content of the hays (Table 3) indicate they are borderline-to-deficient in several nutrients. The total digestible nutrients (TDN) for the hays were significantly different ($P = .0352$). The TDN value for fescue (34.14%) was lower ($P < .05$) than that for brome (43.70%) or prairie hay (41.52%) because of the lower digestible crude fiber and nitrogen-free extract. The daily amounts of TDN consumed by horses fed prairie hay and fescue were below those recommended by NRC; consumption of brome was marginal. The percentage of digestible crude protein of prairie hay (1.53%) was below the amount required for these horses (3.77–3.92%); brome and fescue contained adequate levels: 6.09 and 4.94%, respectively.

Nitrogen balance data (Table 2) did not substantiate the data on protein digestibility. Horses showed a negative nitrogen balance on all three hays. A negative nitrogen balance with prairie hay was expected because the hay's low total and digestible crude protein added to a borderline digestible energy intake. The animals on brome were in positive nitrogen balance for one trial and in negative balance in the other, even though the amount of digestible crude protein was more than adequate and the digestible energy nearly adequate. Brome used in Trial 1 contained 7.71% crude protein; in Trial 2, 11.17%. Fescue hay consistently gave negative nitrogen balances with adequate digestible protein but inadequate energy. Extrapolations of nitrogen intake to maintain a zero balance were found to be near 36, 89, and 75 grams for prairie, brome, and fescue, respectively.

Further analysis of the hay samples for acid detergent, hot-water insoluble ammonia, and urease nitrogen were made to partition nitrogenous components (Table 4). The totals were subtracted from Kjeldahl nitrogen to give an unidentified nitrogen component. If we assume hot-water insoluble nitrogen is the true protein value available to the animal, the estimated digestible true-protein values would be 1.99% for prairie hay, 2.97% for brome, and 2.48% for fescue—less than the digestible crude protein required for the animals in this trial. The only other components that might be available are

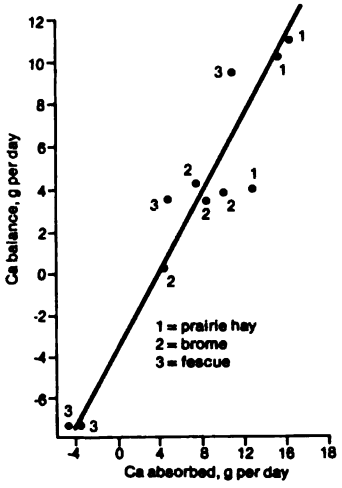


Fig. 1

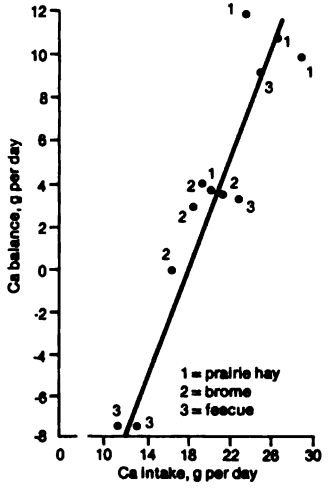


Fig. 2

ammonia and urease nitrogen; however, if these were available, the animals could not have used them efficiently because of the lack of energy from roughage fed in these trials.

Daily calcium intake (Table 2) in prairie hay was adequate (24.95 g/day), compared with the NRC value of 24.76 g/day. It was borderline for brome (19.05 g/day) and inadequate for fescue (17.95 g/day). The balance-studies showed that fescue produced a positive balance in one trial and a negative balance in the next. Brome and prairie hay both produced positive balances. Plotting absorption and balance revealed a zero balance at 4 g of calcium absorbed/day by extrapolation (Fig. 1). A plot of calcium intake and calcium balance showed that an intake of 16 g/day was adequate for a zero balance (Fig. 2), yet that value was less than that of the NRC, suggesting that the established requirement might be high for horses in this age group. The analysis of variance showed significant differences in calcium balance ($P$ = .0173), but Duncan's test showed no significant difference between the hays. Because the calcium balances were so highly significantly different in the analysis of variance, we performed the least significant difference test and found prairie hay (9.40 g/day) to be significantly higher ($P < .05$) than fescue (−0.43 g/day) and brome (2.89 g/day). That showed a problem with Duncan's test, which uses the mean square value of the error term as its basis for calculation.

Phosphorus balance was negative for prairie hay, which was expected in that the daily phosphorus intake by the horse was much less than the NRC requirement. Prairie hay was statistically lower than brome ($P < .05$) but

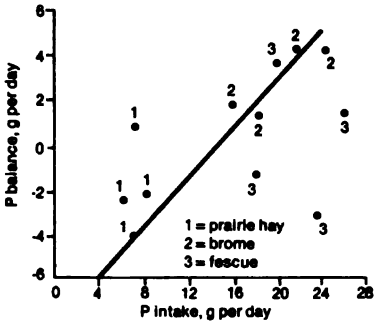


Fig. 3

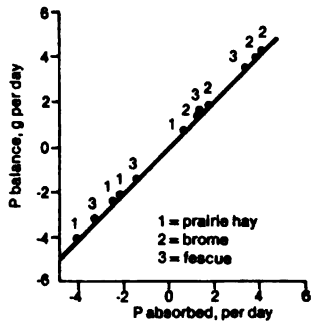


Fig. 4

brome and fescue and fescue and prairie hay were similar. The phosphorus contents of brome and fescue were more than adequate and a positive balance was attained. When intake was extrapolated to zero balance, a value of 15 g/day was obtained (Fig. 3), which corresponded with the NRC values. When absorption was extrapolated to zero balance, a value of nearly 0 was obtained (Fig. 4), showing that the horse has a tremendous ability to recycle phosphorus.

The results of these studies showed that prairie, brome, and fescue hays do not contain adequate protein, energy, or minerals to constitute the sole maintenance diet for a horse. If intake could have been increased, which might be possible in a natural environment, brome might have been adequate in energy. We recommend additional feedstuffs to meet the limitations in protein, energy, calcium, and phosphorus.

Depending on price, one might add 500 grams of cracked corn, sorghum grain, or rolled oats, with 9–11 grams of added calcium. They would provide more than enough energy and a slight excess of protein. Mineral supplements would be necessary when feeding these hays because they are deficient in calcium; also the added grains would need to be supplemented with calcium because they too are low in this mineral.

## References

A.O.A.C. 1975. Official methods of analysis (12th ed.). Association of Official Agricultural Chemists, Washington, D.C.

Barr, A. J., J. H. Goodnight, J. P. Sall, and J. T. Helwig. 1976. Statistical analysis systems. Statistical Analysis Systems Institute Inc., Raleigh.

Conway, E. J. 1963. Microdiffusion analysis and volumetric error. Chemical Publishing Co., New York.

Ensminger, M. E. 1977. Horses and horsemanship. Interstate Printers and Publishers Co., Danville.

Evans, W. J., A. Barton, H. F. Hintz, and L. D. Van Vlick. 1977. The horse. W. H. Freeman and Co., San Francisco.

Fonnesbeck, P. V. 1968. Digestion of soluble and fibrous carbohydrate of forage by horses. J. Anim. Sci. 27:1336.

Fonnesbeck, P. V. 1969. Partitioning the nutrients of forage for horses. J. Anim. Sci. 28:624.

Fonnesbeck, P. V., R. K. Lydman, G. W. Vander Noot, and L. D. Symons. 1967. Digestibility of the proximate nutrients of forages by horses. J. Anim. Sci. 26:1039.

Goering, H. K., and P. J. Van Soest. 1970. Forage fiber analysis. USDA Handbook No. 379. p. 20.

National Research Council. 1958. Composition of cereal grains and forages (Pub. 585). National Research Council, Washington, D.C.

National Research Council. 1978. Nutrient requirements of horses. National Academy of Sciences, Washington, D.C.

Pfander, W. H., and M. Bradley. 1975. Feeding light horses. Columbia Extension Division. University of Missouri. No. 2807.

Robertson, J. B., and P. J. Van Soest. 1977. Dietary fiber estimation in concentrate feedstuffs. American Soc. Anim. Sci. 69th Meeting. No. 636.

Schryver, H. F., and H. F. Hintz. 1975. Feeding horses. Extension Publication No. 94. Cornell University, Ithaca.

Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods (6th ed.). Iowa State University Press, Ames.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics, McGraw-Hill Book Co., Inc., New York.

Stillions, M. C., and W. E. Nelson. 1968. Metabolism stall for male equine. J. Anim. Sci. 27:68.

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# Community Structure in High Andean Herpetofaunas

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ABSTRACT

Density, diversity, niche breadth and niche overlap were obtained and analyzed for amphibians and reptiles in 10 study sites above tree line in the Andes. Two to eight species were found at each site; a total of 1373 specimens of 33 species was studied.

Species richness shows no clear latitudinal trends; there is a trend for increasing species richness in reptiles from equatorial to temperate sites, and there is a greater richness of amphibians in the equatorial sites. Two niche dimensions were analyzed—structural habitat and food. Niche breadth values for structural habitat are essentially the same in reptiles and in amphibians. Niche breadth values for food are higher in amphibians than in reptiles. Overall niche breadth is slightly higher in amphibians than in reptiles. Niche overlap for structural habitat is higher than that for food. Overlap values between any pairs of species at the same site are generally low, with the exception of some pairs of amphibians in which values are relatively high. However, there is no consistent difference in values within and between communities. Niche overlap increases with decreasing species richness and species diversity.

Compared with the adjacent lowlands, the herpetofauna of the high Andes is depauperate, and at any one locality the fauna seldom exceeds eight species. Furthermore, the Andes extend as an essentially unbroken mountain chain through 60° of latitude from the tropics to cool temperate regions. Thus, it is possible to study the relatively simple high montane communities along a latitudinal gradient.

We are concerned here with communities of amphibians and reptiles that occur above tree line—principally in habitats commonly known as *páramo* and *puna*, but areas of Patagonian scrub are included in the southern Andes. Data on biomass, life histories, and geographical distributions will be presented elsewhere.

In the analysis of these small communities, we posed the following questions: 1) What is the composition of the Andean herpetofaunal communities, and how does the composition change geographically? 2) How are various resources used within communities, and how does the use change with different species composition? 3) What kind of relationship exists between species richness and niche breadth within a community? 4) What kind of relationship exists between species richness and niche overlap within a community? 5) Is niche overlap greater among pairs of allopatric species than among pairs of sympatric species? Finally, we attempt to place the quantitative analyses within a naturalistic perception of the communities.

## METHODS

Field studies of Andean communities were initiated by Duellman in June 1974 and terminated in June 1975. Although studies were carried out at 34 sites, quantitative sampling (quadrats) was done at only 10 sites (Appendices 1 and 2). Data on 1373 specimens of 33 species of amphibians and reptiles were obtained from the 10 sites (Table 1).

At each site ten 10 × 10 m quadrats were selected. Physical features, such as slope, soil, hydrography, and weather were noted. The height and percentage cover of each kind of plant was determined. Each quadrat was collected systematically, and all amphibians and reptiles were removed. For each individual, the following data, among others, were recorded: 1) structural habitat (11 categories), 2) height above ground (5 categories), and 3) proximity to water (7 categories). Each specimen was preserved within 12 hr after the following data were taken: 1) snout-vent length, 2) weight, and 3) volume (by displacement). Subsequently, the sex, maturity, and reproductive condition (6 categories) of the specimens were determined. The stomachs of all specimens were emptied, and the numbers of each kind of prey item in each stomach were noted; most arthropod prey were identified only to order, and no attempt was made to identify plant material. Subsequently, all prey items in the same category from the same species at one site were combined and centrifuged; the volume of the resulting pellet was determined to the nearest 0.1 ml.

Although our first analyses of niche dimensions included five parameters, subsequent and final analyses were confined to only two—structural habitat and food. Both of these are independent, whereas parameters such as height and distance from water were in some measure related to structure of the habitat. Because irregularities of weather at the different sites precluded the gathering of comparable data, activity pattern as a niche dimension was eliminated from the statistical analyses. Nevertheless, general activity patterns are discussed later.

The values for species diversity were calculated by the Shannon index (Shannon and Weaver, 1963):

$$H = -\sum_{i}^{s} \frac{n_i}{N} \ln \frac{n_i}{N},$$

where H is the diversity expressed in bits, $s$ is the number of species in the sample, $n_i$ is the number of individuals of the $i$th species, and N is the total number of individuals in the sample.

The amplitude of utilization of resources was determined by the method presented by Colwell and Futuyma (1971):

$$B_i = -\sum_{j} p_{ij} \ln p_{ij},$$

where $B_i$ is niche breadth for the $i$th species, and $p_{ij}$ is the proportion of individuals of the $i$th species associated with resource $j$. Niche breadth values were determined only for samples of species containing seven or more individuals.

The overlapping use of a resource by pairs of species was calculated by:

$$C_{ih} = 1 - \tfrac{1}{2} \sum_{j} |p_{ij} - p_{hj}|,$$

where $C_{ih}$ is the niche overlap value (ranging from 0 to 1) for the $ih$ species pair, $p_{ij}$ is the proportion of individuals of the $ih$ species associated with resource $j$, and similarly $p_{hj}$ involves the $h$th species (Colwell and Futuyma, 1971). Overall niche overlap ($a$) was obtained as an average of the same set of resources used for niche breadth; this is Cody's (1974) summation alpha. The average is obtained, as follows:

$$a = \left(\sum_{i=1}^{n} \alpha_i\right) \Big/ N,$$

where $\alpha_i$ is the community matrix of niche overlap for a particular resource set, and N is the number of resource sets.

The ecological relationships among the different species in every community (site) and grouping of these species was determined by cluster analysis programs in the NTSYS-3 package and was accomplished by the unweighted pair-group method using arithmetic means (Sokal and Rohlf, 1969). In all ecological analyses each species at each site is treated as a unit. Thus, due to the occurrence of some species at two or three sites, the 33 species are treated as 45 units.

## Results

The numbers of species at the 10 sites vary from two (A, G) to eight (J), with amphibian species more numerous at northern sites and reptile species more numerous at southern ones (Table 1). Species diversity indices vary from 0.17 at site C that contains only three species to 1.56 at site E con-

| | | |

Table 2. Niche overlap values of amphibians and reptiles at 10 Andean sites compared with species diversity and overall niche breadth. (N = total species/species used for niche breadth.)

| Site | Species N | Mean species diversity | Overall niche breadth | Mean niche overlap | | |
|---|---|---|---|---|---|---|
| | | | | Structural habitat | Food | Overall |
| A | 2/1 | 0.30 | 1.35 | 0.90 | 0.11 | 0.51 |
| B | 7/4 | 1.35 | 1.35 | 0.77 | 0.25 | 0.51 |
| C | 3/1 | 0.17 | 1.37 | 0.97 | 0.22 | 0.59 |
| D | 4/3 | 1.21 | 1.03 | 0.93 | 0.28 | 0.61 |
| E | 7/5 | 1.56 | 1.47 | 0.43 | 0.20 | 0.31 |
| F | 4/2 | 0.80 | 0.94 | 0.42 | 0.19 | 0.30 |
| G | 2/2 | 0.18 | 1.19 | 0.90 | 0.27 | 0.58 |
| H | 4/2 | 1.25 | 0.21 | 0.27 | 0.38 | 0.33 |
| I | 4/1 | 0.98 | 1.05 | 0.20 | 0.26 | 0.23 |
| J | 8/6 | 1.02 | 1.07 | 0.30 | 0.31 | 0.31 |

structural habitat and food for amphibians is −0.10, for reptiles −0.05, and for amphibians and reptiles combined −0.08.

Overall niche breadth values in amphibians range from 0.61 in *Pleurodema bufonina* at site J to 1.72 in *Pleurodema marmorata* at site E. Among reptiles, the range of values is from 0.14 in *Phymaturus palluma* at site H to 1.69 in *Liolaemus multiformis* at site E. Overall niche breadth values are, on the average, slightly higher among amphibians ($\bar{x}$ = 1.18; N = 17) than among reptiles ($\bar{x}$ = 1.08; N = 10).

The amount of niche overlap in use of a given resource by pairs of species varies from 0.00 to 0.99 (1.0 = complete overlap). However, the mean overlap in structural habitat is 0.60, for food 0.25, and overall 0.43. In the seven sites north of Argentina, the mean niche overlap values for structural habitat are consistently higher than those for food, whereas in the three Argentinian sites (H–J) the reverse is true (Table 2).

In an effort to assess more effectively the values of niche overlap, the entire sample of species was divided into nocturnal and diurnal taxa. Within each of these groups, overlap values were determined for all species pairs for structural habitat, food, and overall overlap (Fig. 1). These analyses show that mean overlap values for nocturnal species are higher than for diurnal ones. The greatest discrepancy is in structural habitat. The 106 overlaps with values of more than 0.9 is an artifact of sampling; most nocturnal frogs were found in their diurnal retreats—under rocks. Among the diurnal species, 11 overlaps in structural habitat have values of more than 0.9. Examination of overlap values for food among these 11 pairs of species reveals that the values for food range from 0.00 to 0.55. The highest value occurs between the iguanid lizards *Liolaemus kriegi* at site I and *Phyma-*

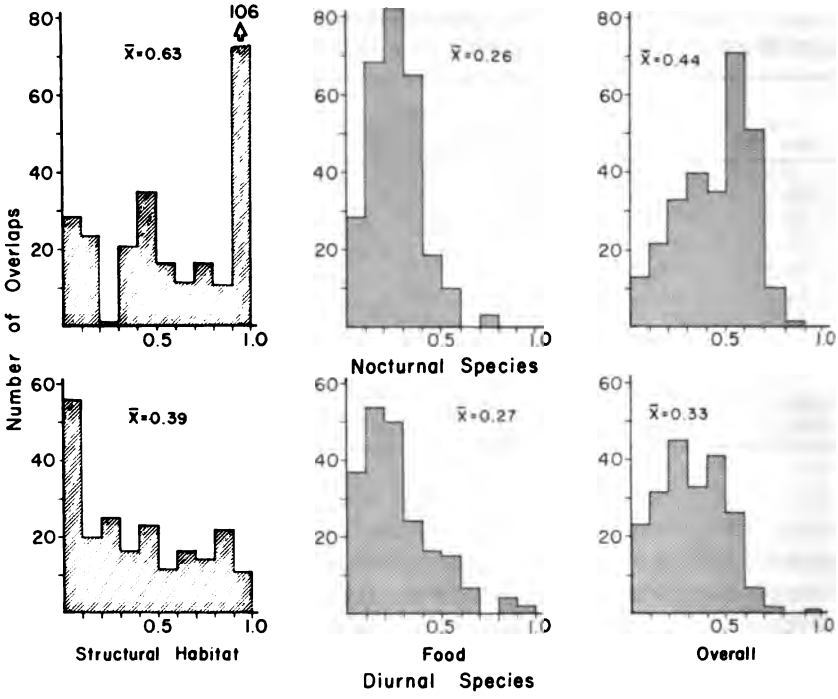


Fig. 1. Frequency distributions of niche overlap values for amphibians and reptiles at 10 Andean sites.

*turus palluma* at site H; the two species are not sympatric. Likewise, a value of 0.26 exists between the microteiid lizards *Proctoporus columbianus* at site B and *Proctoporus bolivianus* at site D; again the species are widely allopatric. A value of 0.39 between the sympatric lizards *Liolaemus bibronii* and *Liolaemus darwinii* indicates that these two lizards are using the same structural habitat and ingesting similar kinds and amounts of prey at site J.

The introduction of broad categories of activity—diurnal and nocturnal—into the analysis provides some additional information, as noted in the distinction of these categories in relation to niche overlap (Fig. 1). Niche breadth values for structural habitat are higher for diurnal species (0.64) than for nocturnal ones (0.43). As noted previously, most nocturnal species were found in their diurnal retreats (under rocks); thus, the niche breadth values for many species probably reflect this bias. Niche breadth values for food are 1.66 (diurnal) and 1.84 (nocturnal), resulting in similar overall niche breadth values (1.12—diurnal; 1.15—nocturnal).

The combination of sites into three geographic regions and analyses of the data regionally provides additional information on patterns. Sites A, B, and C in the Cordillera Oriental of the northern Andes are separated from

Table 3. Comparison of ecological values in three Andean regions. (N = total species/species used for niche breadth.)

| Region | Total species N | Mean species diversity | Mean niche breadth | | | Mean niche overlap | | |
|---|---|---|---|---|---|---|---|---|
| | | | Str. habitat | Food | Overall | Str. habitat | Food | Overall |
| Northern | 12/6 | 0.61 | 0.42 | 2.28 | 1.35 | 0.88 | 0.19 | 1.54 |
| Central | 17/12 | 0.94 | 0.54 | 1.88 | 1.22 | 0.67 | 0.23 | 0.45 |
| Southern | 16/9 | 1.08 | 0.51 | 1.29 | 0.88 | 0.26 | 0.32 | 0.29 |

the central sites D, E, F, and G in the Andes of southern Perú and the Altiplano of Perú and Bolivia. Sites H, I, and J in Argentina are grouped as the southern unit. Species diversity is highest and overall niche overlap is lowest in the southern region, and overall niche breadth is highest in the central region (Table 3). The relative numbers of nocturnal and diurnal species changes regionally, with the southern region having the fewest nocturnal species but the most diurnal ones.

The final analysis involved clustering of the species on the basis of five parameters; again each species at each site was treated as a separate unit (Fig. 2). Although all similarity coefficients are less than 0.5, some clusters seem to reflect actual ecological relationships. The highest coefficient (0.438) is between populations of *Homonota darwinii* at sites I and J. The next highest coefficient (0.350) is between *Phrynopus peruvianus* (site D) and *Eleutherodactylus curtipes* (site C)—allopatric, cryptophilic, nocturnal species. The only other coefficients above 0.3 are 0.315 for two pairs of allopatric species of nocturnal frogs. Further examination of the phenogram (Fig. 2) reveals several salient features: 1) The majority of southern diurnal lizards (sites H, I, and J) are clustered together, but their coefficients of similarity are less than 0.2. 2) With the unexplainable exception of *Hyla labialis*, all of the frogs from the northern sites are included in one major cluster. 3) Within the major clusters, species from a given site are distributed throughout the cluster.

## Discussion

It is difficult to determine both the extent of resource utilization within given communities and the differences between communities, for we have only crude measurements of some of the available structural resources and no data on food resources. Thus, our view of the resources is limited to our perception of the structural habitat and extrapolations from stomach contents. Furthermore, we are attempting to compare communities in very different and geographically separate environments. Within these constraints we present our interpretations of the results and discuss them in

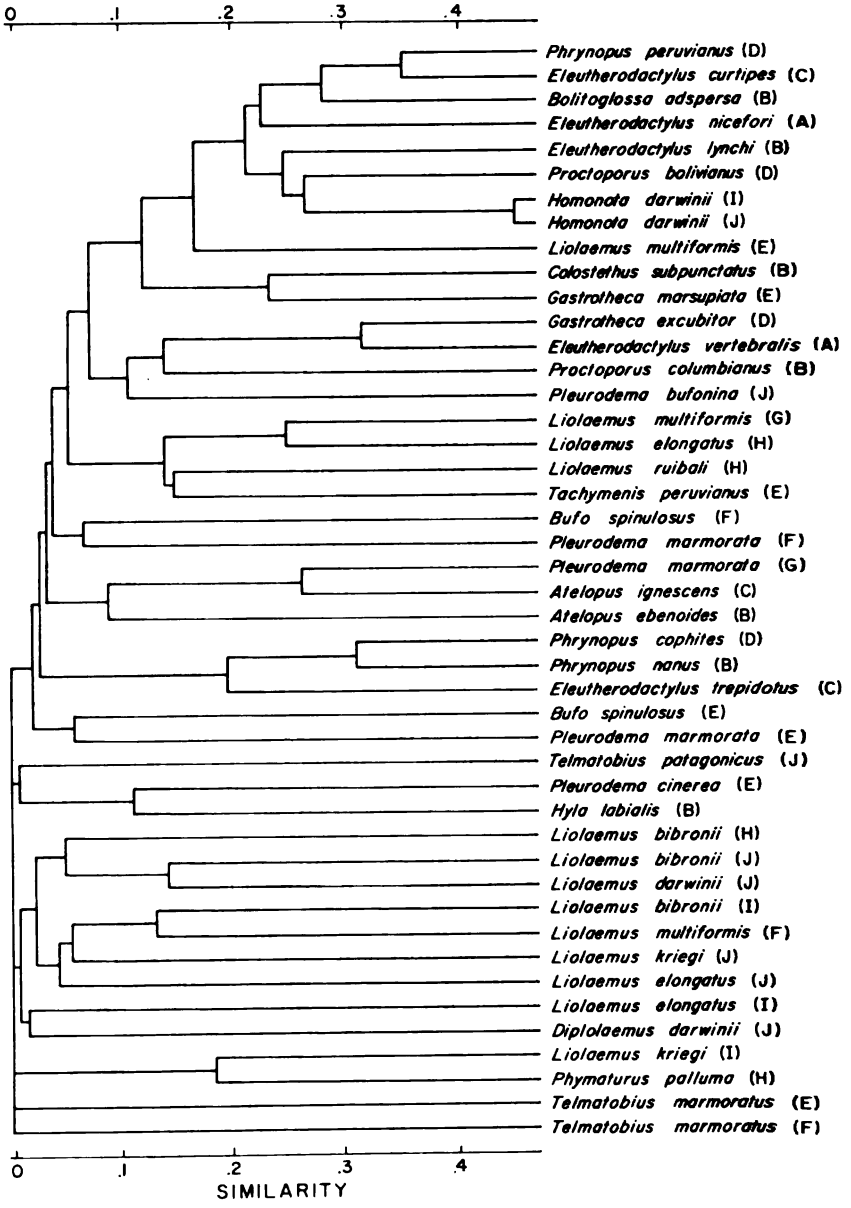


Fig. 2. Cluster analysis of 33 species from 10 Andean sites on the basis of five ecological parameters. Clustering was by the unweighted pair group method using arithmetic means. The cophenetic correlation coefficient is 0.874. Letters refer to sites (see Appendix I).

light of relevant information on other communities and of current ecological theory.

Our results show that the herpetological communities in the Andes are composed of few species—no more than eight at any given site. Data from the 10 study sites and from additional localities show that there are three major faunistic regions: 1) The Andes of Colombia and Ecuador, with some generic affinities with the Cordillera Oriental in Perú; 2) The central Andean region and Altiplano in Perú and Bolivia; and 3) The southern Andes in Argentina and Chile (Duellman, 1979). Within any one of these regions species composition gradually changes geographically and changes abruptly in response to local environmental conditions. For example, the small leptodactylid frog *Pleurodema marmorata* is widespread from central Perú to northern Bolivia, whereupon *Pleurodema cinerea* extends southward into northern Argentina. The two species occur in sympatry in the Titicaca Basin. Local conditions dictate the presence of certain species; for example, the presence of crevices in extrusive basaltic and andesitic rocks apparently is necessary for *Phymaturus palluma*.

The data on food provide no evidence for sharp geographic limits to distributions owing to competition for food. Most reptiles and amphibians are opportunistic feeders and consume a wide variety of prey, the major limiting factor being the maximum size of the prey. With the possible exception of the herbivorous species, no Andean amphibian or lizard is a feeding specialist. We do not have data on the kinds of plants eaten by the herbivorous lizards; they may be selective in their browsing. Pearson (1954) noted that *Liolaemus multiformis* feeds on leaves and blossoms of *Nototriche*, but it also may feed on other tola shrubs (*Lepidophyllum*, *Baccharis*, and *Senecio*).

With the exception of the aquatic species of *Telmatobius* (two species in the study sites), all of the included Andean herpetofauna are terrestrial. Most species seek shelter below ground (most frequently they are encountered under rocks), but some use the bases of bunch grasses and bushes or crevices in rocks. Thus, the vertical component of the structural habitat is limited to a few cm. Andean iguanid lizards (*Diplolaemus*, most species of *Liolaemus*, and *Phymaturus*) are always associated with rocks; these are used for basking sites, feeding stations, and display sites, and the lizards seek shelter beneath them. Therefore, it is not surprising that there is a positive correlation between the numbers of species and individuals of Andean reptiles (mostly iguanid lizards) and the percentage of rock coverage. Furthermore, it is equally understandable that no positive correlation exists between percentage of rock coverage and amphibian diversity, for although percentage of rock coverage generally increases from north to south (Table 1), the number of amphibian species diminishes. If we concerned ourselves with the entire amphibian fauna of the Andes, rather than solely with those

species encountered in the study sites, we would find much greater amphibian diversity in the north, which seemingly correlates with the much higher percentage of vegetation cover in the northern Andes. For example, 71 species of amphibians are known to occur in the high Andes of Colombia, whereas only 15, nine of which are aquatic *Telmatobius*, inhabit the Andes of Argentina and Chile north of the austral forests. The luxuriance of the vegetation and the diversity of the amphibian fauna both apparently are due to more equable and mesic conditions in the north, as compared to the more arid southern Andes, which are subjected to more extreme seasonal fluctuations in temperature.

We found no correlation between lizard species richness and vegetational diversity throughout the geographic breadth of our samples. This seems to contradict the conclusions of Pianka (1966, 1967, 1973), who showed positive correlations between plant foliage height diversity with the richness and diversity of the saurian faunas. This apparent contradiction may be due to the small size of our study sites, but more likely is a reflection of our comparing highly diverse montane samples in contrast to the more uniform desert communities studied by Pianka.

Although the southern sites (H–J) are relatively arid, water was present at most of the sites (Table 1). There is a positive correlation ($r = 0.75$; $P < .05$) between the percentage of coverage of water at a site and the number of species of amphibians having aquatic larvae. It should be pointed out that all anurans at the southern sites employ the primitive reproductive mode of placing eggs in standing water (Salthe and Duellman, 1973), whereas in the more northern and mesic sites a diversity of reproductive modes is found—eggs in streams (*Telmatobius* and *Atelopus*), egg-brooding in dorsal pouch (*Gastrotheca*), eggs on land and tadpoles carried to water (*Colostethus*), and direct development of terrestrial eggs (*Eleutherodactylus* and *Phrynopus*). There is also a latitudinal gradient in the mode of life history in lizards. The northern lizards (*Proctoporus*) inhabiting the more equable and mesic environments are oviparous, whereas most of the iguanids of the southern Andes are viviparous, an adaptation to egg-brooding at high elevations (Donoso-Barros, 1966; Greer, 1968; Fitch, 1970).

Considerable diversity exists in the types of food eaten and feeding strategies of the species. The amphibians are carnivorous, mostly insectivorous. The lizards, *Homonota* and *Proctoporus*, feed on small insects, whereas *Diplolaemus* feeds on a variety of insects and also preys on small lizards. *Phymaturus* is strictly herbivorous, and the species of *Liolaemus* are omnivorous. *Liolaemus multiformis*, which occurs at higher elevations than any other lizard in the Andes, changes its diet with age; juveniles are strictly insectivorous, whereas subadults are omnivorous, and adults are almost completely herbivorous. We can assign the diurnal frogs *Atelopus* and *Colostethus* to the category of active foragers, whereas the other frogs (all

nocturnal) use the "sit and wait" strategy (Pianka, 1966). Most, if not all, of the lizards are active foragers.

In the Andean communities the extent of resource utilization by the component species seems to be independent of the numbers of species and individuals. Amphibians have greater trophic niche breadths than do reptiles (Appendix 3), and trophic niche breadths are greater in northern sites than in others; the geographic difference probably is a reflection of the preponderance of amphibians in the north, where trophic niche overlap is lower than elsewhere (Table 3). The mean trophic niche breadth of lizards (1.64) is much smaller than those of 3.8, 3.9, and 4.4 for lizards inhabiting three lowland deserts (Pianka, 1973) and slightly smaller than 2.18 for *Tropidurus peruvianus* in coastal Perú (Péfaur, ms.). Different formulae were used by Pianka and us to express niche breadth, but according to comparisons of indices by Peet (1974), the values obtained by Simpson's index (used by Pianka) should be lower than the values obtained by the Colwell-Futuyma index used by us. Without comparative data on the diversity of available food resources from the different regions no conclusions can be drawn, although it seems reasonable to hypothesize that food diversity in the Andes, like the diversity of the lizards, is much lower than in the lowland deserts.

With the exception of the crevice-dwelling, herbivorous *Phymaturus palluma,* no Andean species seems to be highly specialized for food and structural habitat. With reference to bird communities, Cody (1974:66) generalized: ". . . that the habitat specialists are food generalists, and that the food specialists are habitat generalists." Our results provide slight support for that generalization. Non-significant negative correlations exists between habitat niche breadth and trophic niche breadth (−0.11 in amphibians, −0.05 in reptiles, −0.08 in amphibians and reptiles combined).

Niche overlap scores are inconsistent with theory, taxonomic group, and in general with geography. As noted by Fuentes (1976), pairs of analogous species in different communities are expected to be more similar to each other in their use of resources than are pairs of species within a community. Comparison of overlap values of species within a given community with values of those species with others in different communities reveals no consistent differences. In fact, in some cases overlap values within communities are notably higher than values between communities. Generally niche overlap scores and coefficients are low (Fig. 2). The mean overlap values of structural habitat (0.26) and food (0.32) in the three Argentinian sites are lower than those for lizard communities in three lowland deserts—structural habitat 0.31 and food 0.47 (Pianka, 1973).

Perhaps the comparison of niche breadth and overlap scores of lizards in lowland deserts and Andean communities is not justified. However, lower scores for niche breadth and overlap in the Andean communities might be

interpreted as the Andean species being more specialized. This suggestion is consistent with lower overlap. Pianka (1975:311) noted: "In sum, species diversity in rich saurofaunas is *not* facilitated by increased overlap; rather, quite the reverse is true: overlap tends to decrease with increasing species density." Our data seem to support Pianka's findings; there is a non-significant correlation of −0.44 between species density and mean overall niche overlap in the 10 Andean sites. The agreement of our results with those of Pianka is surprising in that he was working with large communities (4–40; $\bar{x}$ = 15.7 species). These results are contrary to the theory that increased species diversity results in increased niche overlap or competition (MacArthur, 1972). As emphasized by Duellman (1978), there is no empirical evidence for increased competition in herpetofaunal communities in tropical rainforests, where species diversity is greatest.

We find that there is no correlation between species richness (density) and overall niche breadth in a given community. Also we find that niche overlap values within and between communities are inconsistent, and finally we find that niche overlap is negatively correlated with species density.

Nevertheless, it remains for us to explain why these small Andean herpetofaunal communities are structured the way they are. Here we depart from the quantitative approaches and involve naturalistic observations in an evolutionary context. In so doing, we are especially mindful of Whitford's (1977) concerns about the over-computerization of ecology.

As a starting point we provide an ecological classification of the herpetofauna of the 10 sites (Fig. 3). Examination of the phylogenetic relationships and distributions of the species reveals that all of the heliophilic terrestrial species (all are iguanid lizards) are Patagonian in origin; only *Liolaemus* has deeply invaded the Andes (to central Perú) (Duellman, 1979). The dry Patagonian region has mild summers and cold winters. In lizards, omnivory and herbivory are primarily associated with dry and/or cold regions. Very few lizards in tropical forests feed on plants; of 38 species of lizards recorded from the Iquitos region of Perú by Dixon and Soini (1975), only one is herbivorous and one omnivorous, and Duellman (1978) found only one omnivore among 29 species in the upper Amazon Basin in Ecuador. Furthermore, the low thermal requirements and viviparity of the Patagonian lizards can be viewed as adaptations that also permit existence in the harsh Andean environments. The small gecko, *Homonota*, belongs to a genus endemic to cis-Andean temperate South America, and the viviparous snake, *Tachymenis*, is a member of an austral group extending in the Andes to central Perú. Among the six species of frogs that are austral in origin, the three species of *Pleurodema* are related to species in the mesic austral forests (Duellman and Veloso, 1977). Two of these (*P. bufonina* and *P. marmorata*) deposit their eggs in water, whereas *P. cinerea* constructs a foam nest—an adaptation for reducing desiccation (Heyer, 1969). *Bufo spi-*

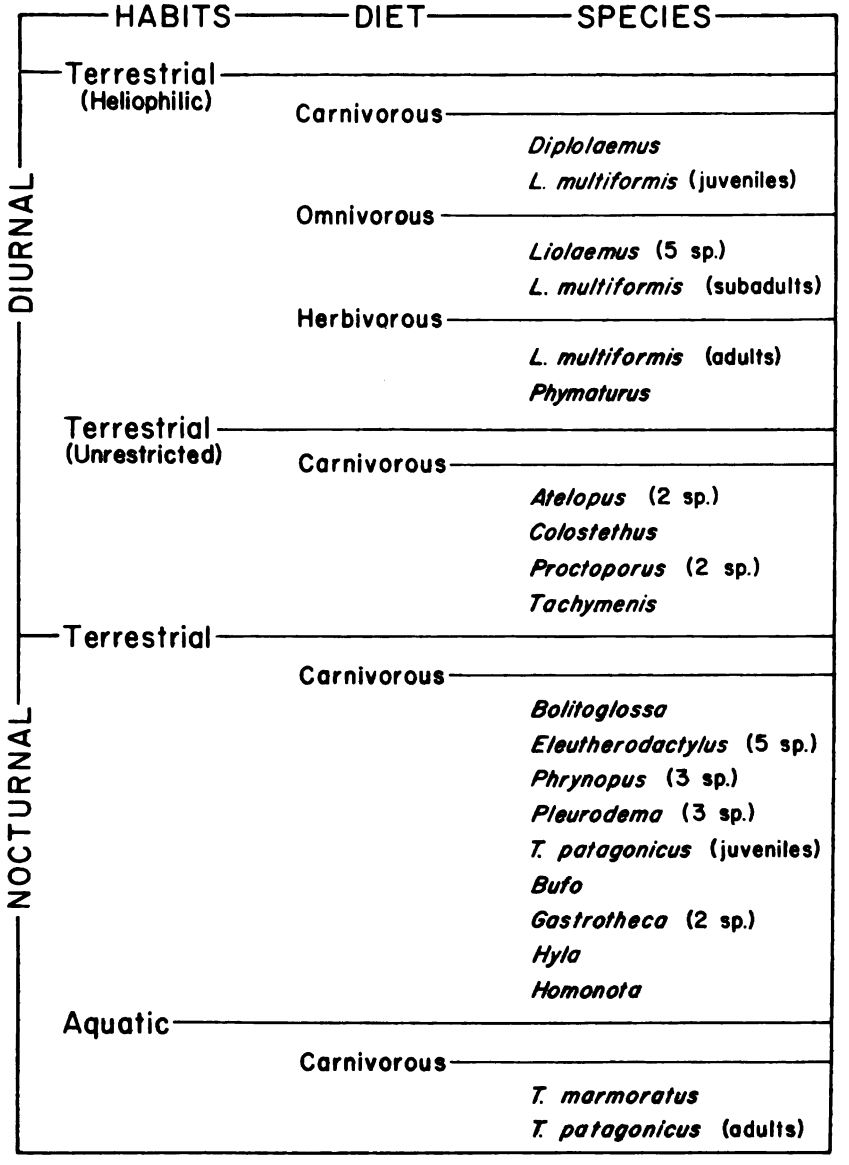


Fig. 3. Ecological classification of amphibians and reptiles occurring in 10 Andean sites.

*nulosus* is a xeric-adapted species related to toads inhabiting cool austral forests. The two species of *Telmatobius* belong to the only genus of austral frogs that is speciose and widely distributed in the Andes; all members of the genus are aquatic.

Thus, all of the southern and most of the central Andean communities are composed of species that have adaptations of xeric and cold conditions (see Pearson, 1954, and Pearson and Bradford, 1976, for discussions of behavior and physiological adaptations of *Liolaemus multiformis* and *Bufo spinulosus*; Donoso-Barros, 1966, for observations on various iguanid lizards; and Vellard, 1951, and Macedo, 1960, for observations on *Telmatobius*).

The small teiid lizards *Proctoporus*, the salamander *Bolitoglossa*, and the frogs of the genera *Atelopus*, *Colostethus*, *Eleutherodactylus*, *Phrynopus*, *Gastrotheca*, and *Hyla* all belong to the northern Andean assemblage (Duellman, 1979). The species in the northern high Andes are all related to, and possibly derived from, congeners inhabiting cloud forests on the Andean slopes or lowland tropical rainforest. Most of the Andean regions inhabited by these species are mesic and cool. Thus, physiological adaptations to existence in the high Andes is primarily a matter of lower thermal requirements than those exhibited by lowland relatives. Consequently, the communities are composed principally of amphibians, the majority of which are nocturnal. The lizards are cryptic in their behavior, entirely unlike the larger heliophilic iguanids in the south.

It is obvious that historical factors must be considered in consort with ecological and physiological characteristics when interpreting the evolution of the high Andean communities. All of the species are derived from lowland stocks, and their evolution is relatively recent. The Andean orogeny began only in the Miocene; the entire cordillera has been subjected to drastic climatic fluctuations, and many of the areas of the study sites were affected by glaciation in the Pleistocene (Dollfus, 1964; Patterson and Lanning, 1967; Kinzl, 1968; Vuilleumier, 1971). The depauperate high Andean herpetofauna can be explained by either: 1) There has been insufficient time for many species to invade the Andes. 2) Only a few species have evolved physiological tolerances that have allowed them to invade the Andes. 3) The environments are saturated. Because of the widespread distribution of some Andean species, the second explanation seems to be the most plausible.

Thus, species richness primarily is a function of historical factors and rigid physiological requirements. Consequently, the low numbers of species and lack of any consistent latitudinal gradients in species richness are readily understandable, especially since the faunas of the northern and southern Andes were derived independently, and the fauna of the central Andes is a mixture of the two assemblages (Duellman, 1979). Physiologically, most of the Andean species are specialists by comparison with their lowland relatives. Narrow niche breadths are indicative of specialization to structural habitat and to food, and low niche overlaps suggest that in most instances sympatric species are at least partly segregated ecologically. The dimensions of these measurements might manifest speculation that competition is important in regulating species densities in these communities.

but this is contrary to evidence on the relationship of species richness and niche overlap.

A better understanding of the evolution of the Andean communities might be acquired by comparing southern Andean communities with those in the adjacent deserts, steppe, or Patagonian regions of Argentina and by comparing northern communities with those at lower elevations.

## CONCLUSIONS

The foregoing analyses and their interpretations provide a basic insight into the community structure of herpetological faunas in the high Andes. The principal results can be summarized, as follows:

1. Andean herpetofaunal communities consist of eight or fewer species, all of which have evolved physiological tolerances for existence in extreme environments, and all of which are derived from lowland ancestral stocks.
2. Community composition changes geographically, due primarily to the existence of a northern and a southern assemblage of species.
3. Differences in species composition in different communities in one region principally reflects differences in structural habitat.
4. Significant positive correlations exist between numbers of species and individuals of reptiles with percentage of rock cover in the habitat.
5. Non-significant negative correlations exist between habitat niche breadth and trophic niche breadth.
6. There is no correlation between overall niche breadth and species richness. Therefore, in these small communities the extent of resource utilization by the component species is independent of the numbers of species and individuals.
7. Niche overlap values generally are low, and there is no consistent difference in values within and between communities.
8. Generally, niche overlap increases with decreasing species diversity and species richness, but the correlations are not significant.

## RESUMEN

Se estudian diez pequeñas comunidades de anfibios y reptiles de la región altoandina, incluyendo páramos, punas y matorrales patagónicos, donde se averiguan la composición taxonómica, la densidad, la diversidad específica, y la amplitud y el sobremontaje del nicho ecológico de 33 especies.

Estas especies incluyen 1373 individuos; pero no más de ocho especies aparecen juntas en una misma comunidad. Los anfibios son más abundantes en la región ecuatorial, mientras que los reptiles incrementan hacia el sur. Todas estas especies altoandinas han desarrollado diversos mecanismos fisiológicos de tolerancia a las condiciones extremas de los ambientes. La diferencia encontrada en la composición taxonómica de las comunidades refleja principalmente diferencias en la estructura del ambiente.

El nicho ecológico fue estudiado en base a la estructura del ambiente, el alimento, y a ambas características integradas. La amplitud del nicho estructural es similar entre anfibios y reptiles, mientras que las amplitudes del nicho alimentario y del nicho total son mayores en los anfibios que en los reptiles. El sobremontaje de los nichos tiene valores bajos y, en general, su valor aumenta con la disminución de la diversidad específica y composición taxonómica. El sobremontaje es mayor en el nicho estructural que en el alimentario.

La estructura de las comunidades en la forma presente responde a varios factores. Comportamientos que modifican la tolerancia a la temperatura, alimentarios, y reproductivos son importantes en la adaptación y ocupación de los ambientes andinos.

La relativamente pobre composición taxonómica de las comunidades probablemente responde al orígin de las especies. La mayoría, sino todas, se han originado en tierras bajas y sólo a través de ganancias fisiológicas de alto valor adaptativo han podido conquistar la parte alta, por sobre la línea de los árboles, de los Andes.

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## Literature Cited

Cody, M. L. 1974. Competition and the structure of bird communities. Princeton Univ. Press, New Jersey, 318 pp.

Colwell, R. K., and D. J. Futuma. 1971. On the measurement of niche breadth and overlap. Ecology 52:567–576.

Dixon, J. R., and P. Soini. 1975. The reptiles of the upper Amazon Basin, Iquitos region, Peru I. Lizards and amphisbaenians. Contr. Biol. Geol. Milwaukee Publ. Mus. 4:1–58.

Dollfus, O. 1964. Cambios climáticos Cuaternarios en los Andes Peruanos. Bol. Soc. Geog. Lima 83:65–74.

Donoso-Barros, R. 1966. Reptiles de Chile. Ed. Univ. Chile, Santiago, 458 p.

Duellman, W. E. 1978. The biology of an equatorial herpetofauna in Amazonian Ecuador Misc. Publ. Mus. Nat. Hist. Univ. Kansas 65:1–352.

Duellman, W. E. 1979. The herpetofauna of the Andes: Patterns of distribution, origin, differentiation, and present communities. Pp. 371–459 *in* Duellman, W. E. (ed.). The South

American herpetofauna: Its origin, evolution, and dispersal. Monog. Mus. Nat. Hist. Univ. Kansas 7:1–485.

Duellman, W. E., and A. Veloso M. 1977. Phylogeny of *Pleurodema* (Anura: Leptodactylidae): A biogeographical model. Occas. Pap. Mus. Nat. Hist. Univ. Kansas 54:1–46.

Fitch, H. S. 1970. Reproductive cycles in lizards and snakes. Misc. Publ. Mus. Nat. Hist. Univ. Kansas 52:1–247.

Fuentes, E. R. 1976. Ecological convergence of lizard communities in Chile and California. Ecology 57:3–17.

Greer, A. E. 1968. Mode of reproduction in the squamate faunas of three altitudinally correlated life zones in East Africa. Herpetologica 24:229–232.

Heyer, W. R. 1969. The adaptive ecology of the species groups of the genus *Leptodactylus* (Amphibia: Leptodactylidae). Evolution 23:421–428.

Kinzl, H. 1968. La glaciación actual y pleistocénica en los Andes centrales. Pp. 77–90 *in* Troll, C. (ed.). Geo-ecology of the mountainous regions of the tropical Americas. Colloq. Geog. 9:1–223.

MacArthur, R. H. 1972. Geographical ecology: patterns in the distributions of species. Harper and Row, New York, 269 pp.

Macedo, H. de. 1960. Vergleichende Untersuchungen an Arten der Gattung *Telmatobius* (*Amphibia, Anura*). Zeit. Wissen. Zool. 263:355–396.

Patterson, T. C., and E. P. Lanning. 1967. Los medios ambientes glacial tardío y postglacial de Sudamérica. Bol. Soc. Geog. Lima 86:1–19.

Pearson, O. P. 1954. Habits of the lizard *Liolaemus multiformis multiformis* at high altitudes in southern Perú. Copeia 1954(2):111–116.

Pearson, O. P., and D. F. Bradford. 1976. Thermoregulation of lizards and toads at high altitudes in Perú. Copeia 1976(1):155–170.

Peet, R. K. 1974. The measurement of species diversity. Ann. Rev. Ecol. Syst. 5:285–307.

Pianka, E. R. 1966. Convexity, desert lizards and spatial heterogenity. Ecology 47:1055–1059.

Pianka, E. R. 1967. On lizard species diversity: North American flatland deserts. Ecology 48:333–351.

Pianka, E. R. 1973. The structure of lizard communities. Ann. Rev. Ecol. Syst. 4:53–74.

Pianka, E. R. 1975. Niche relations of desert lizards. Pp. 292–314 *in* Cody, M. L. and J. M. Diamond (eds.). Ecology and evolution of communities. Harvard Univ. Press, Cambridge, 545 pp.

Salthe, S. N., and W. E. Duellman. 1973. Quantitative constraints associated with reproductive mode in anurans. Pp. 229–249 *in* Vial, J. L. (ed.). Evolutionary biology of the anurans: contemporary research on major problems. Univ. Missouri Press, Columbia, 470 pp.

Shannon, C. E., and W. Weaver. 1963. The mathematical theory of communication. Univ. Illinois Press, Urbana, 117 pp.

Sokal, R. R., and F. J. Rohlf. 1969. Biometry. Freeman and Co., San Francisco, 776 pp.

Vellard, J. 1951. Estudios sobre batracios Andinos I. El grupo Telmatobius y formas afines. Mem. Mus. Hist. Nat. Javier Prado 1:1–89.

Vuilleumier, B. S. 1971. Pleistocene changes in the fauna and flora of South America. Science 173:771–780.

Whitford, P. B. 1977. Is ecology over-computerized? Bull. Ecol. Soc. Amer. 58:5–6.

## Appendix 1

Pertinent data on the 10 study sites include: 1) location, 2) geographic coordinates, 3) elevation, 4) dates of study, and 5) general description composed of exposure, substrate, hydrography, weather, and vegetation.

Site A.—COLOMBIA: *Norte de Santander:* 32 km S Chitagá, 3400 m; 06°52′N, 72°42′W; north slope of Páramo de Almorzadero, Cordillera Oriental. 23–24 August 1974. Northern slope with inclinations of 5–35°; dark brown loam with numerous granite boulders; two small (<1 m wide) streams; air 4.0–11.5°C, and 4 mm rain with predominately cloudy skies; páramo with bunch grass and *Espeletia* dominant and also mosses, terrestrial bromeliads, and low (<1.5 m) woody bushes (*Baccharis*).

Site B.—COLOMBIA: *Boyacá:* Vado Hondo, 2660 m; 05°26′N, 72°44′W; valley of Río Cusiana in southern part of Páramo de Vigajual, Cordillera Oriental. 30 August–2 September 1974. Western and southern slopes and flat valley; yellowish brown sandy loam with granitic boulders and talus; many small streams and seepages, one pond, and marshy terrain; air 5.0–19.5°C, 33 mm rain (including hail) with predominately cloudy skies; páramo with bunch grass and mosses dominant and also *Espeletia* and *Baccharis*.

Site C.—ECUADOR: *Napo:* Laguna de Papallacta, 3330 m; 00°19′S, 78°07′W; eastern slope of Cordillera Oriental. 26–27 April 1975. Southern and eastern slopes; dark brown loam with granitic boulders; one small (<1 m wide) stream; air 3.0–14.5°C, sunny with no precipitation; páramo dominated by bunch grass and low herbs, also with ferns and cushion plants.

Site D.—PERÚ: *Cuzco:* Abra Acanacu, 25 km NNE Paucartambo, 3520 m; 13°12′S, 71°42′W; crest of front range (Cadena de Paucartambo) of Cordillera Oriental. 7–9 February 1975. Crest of ridge; dark brown loam with granitic rocks and shale; small temporary ponds in depressions; air 4.0–15.0°C, 6.5 mm rain with partly sunny skies; puna dominated by bunch grass but with many small herbs (especially a small terrestrial orchid), mosses, ferns, and club mosses.

Site E.—PERÚ: *Puno:* 4 km W Santa Rosa, 4010 m; 14°36′S, 70°50′W; northwest end of Titicaca Basin on Altiplano. 2–3 February 1975. Broad valley floor with some short south-facing river terraces; dark brown loamy clay with weathered granitic rocks; Río Santa Rosa bordering south edge of study area, and many small temporary ponds; air 1.5–19.5°C, 9 mm rain with predominately cloudy skies; puna dominated by bunch grass (grazed) with some cushion plants and many lichens and mosses.

Site F.—PERÚ: *Puno:* 5 km W Tincopalca, 4210 m; 15°51′S, 70°47′W; valley in Cordillera Occidental. 30–31 January 1975. Narrow valley (floor ±100 m wide) with irregular slopes to ±45° to heights of ±75 m above valley floor; soil sandy in valley floor and predominately clay on slopes with limestone outcroppings and talus below; permanent stream meandering through valley and small seepage areas on some slopes; air 0.0–20.0°C, 22.5 mm rain with predominately cloudy skies; dry puna with bunch grass, *Senecio*, and small (≤40 cm) bushes (Rosaceae).

Site G.—BOLIVIA: *Cochabamba:* 36 km W Chala, 4380 m; 17°38′S, 66°51′W; crest of Cordillera Oriental. 9–10 November 1974. Rolling terrain

with primarily western and southern exposures; brown sandy clay soil with many sandstone rocks; two small temporary ponds; air −1.5–17.0°C, 2 mm snow; sunny in mornings, cloudy and snowy in afternoons; puna with bunch grass dominant and also scattered low spiny sclerophyllous legumes and cushion plants.

Site H.—ARGENTINA: *Mendoza:* Quebrada del Toro, 8 km E Cruz de Paramillo, 2790 m; 32°34′S, 69°05′W; eastern slopes of Sierra de Uspallata (Andean precordillera). 8–9 December 1974. Ravine ±80 m deep; sandy loam and gravel soils and silicious metamorphic rocks; no water; air −0.5–7.0°C, 29 mm of rain, sleet and snow with completely overcast skies; scattered low bunch grasses, a few bushes (*Adesmia, Senecio, Ephedra*) and cacti.

Site I.—ARGENTINA: *Mendoza:* South slope Paso El Choique, 58 km SSW El Manzano, 1950–2050 m; 36°30′S, 69°50′W; basaltic precordillera, eastern foothills of Andes. 12–13 December 1974. Gentle slopes; reddish brown sandy soil with basaltic rocks; no water; air 4.0–27.0°C; no precipitation under clear skies; Patagonian scrub with *Adesmia* bushes (≤1.5 m) and low (<70 cm) rounded clumps of *Berbinacia, Umbellifera, Tubiflora,* and cacti.

Site J.—ARGENTINA: *Neuquén:* South shore Laguna Blanca, 1275 m; 39°03′S, 70°20′W; lake basin with slight slopes. 15–17 December 1974. Gravel and sand with basaltic rocks and lava extrusions; lake edge; air 6.5–27.0°C, 20 mm of precipitation (hail) with mostly clear skies; sparse vegetation consisting of low (<50 cm) clumps of bunch grass and grayish white *Senecio.*

## Appendix 2

The number of specimens of each species from each of the 10 study sites is given. Letter designation of sites correspond to Appendix 1.

| Species | A | B | C | D | E | F | G | H | I | J |
|---|---|---|---|---|---|---|---|---|---|---|
| *Bolitoglossa adspersa* | — | 31 | — | — | — | — | — | — | — | — |
| *Eleutherodactylus curtipes* | — | — | 83 | — | — | — | — | — | — | — |
| *Eleutherodactylus lynchi* | — | 101 | — | — | — | — | — | — | — | — |
| *Eleutherodactylus nicefori* | 21 | — | — | — | — | — | — | — | — | — |
| *Eleutherodactylus trepidotus* | — | — | 2 | — | — | — | — | — | — | — |
| *Eleutherodactylus vertebralis* | 2 | — | — | — | — | — | — | — | — | — |
| *Phrynopus cophites* | — | — | — | 1 | — | — | — | — | — | — |
| *Phrynopus nanus* | — | 1 | — | — | — | — | — | — | — | — |
| *Phrynopus peruvianus* | — | — | — | 12 | — | — | — | — | — | — |
| *Pleurodema bufonina* | — | — | — | — | — | — | — | — | — | 9 |
| *Pleurodema cinerea* | — | — | — | — | 10 | — | — | — | — | — |
| *Pleurodema marmorata* | — | — | — | — | 30 | 68 | 152 | — | — | — |
| *Telmatobius marmoratus* | — | — | — | — | 1 | 12 | — | — | — | — |
| *Telmatobius patagonicus* | — | — | — | — | — | — | — | — | — | 290 |
| *Atelopus ebenoides* | — | 160 | — | — | — | — | — | — | — | — |
| *Atelopus ignescens* | — | — | 1 | — | — | — | — | — | — | — |
| *Bufo spinulosus* | — | — | — | — | 28 | 6 | — | — | — | — |
| *Colostethus subpunctatus* | — | 104 | — | — | — | — | — | — | — | — |
| *Hyla labialis* | — | 6 | — | — | — | — | — | — | — | — |
| *Gastrotheca excubitor* | — | — | — | 12 | — | — | — | — | — | — |
| *Gastrotheca marsupiata* | — | — | — | — | 7 | — | — | — | — | — |
| *Homonota darwinii* | — | — | — | — | — | — | — | — | 22 | 19 |
| *Diplolaemus darwinii* | — | — | — | — | — | — | — | — | — | 6 |
| *Liolaemus bibronii* | — | — | — | — | — | — | — | 5 | 3 | 10 |
| *Liolaemus darwinii* | — | — | — | — | — | — | — | — | — | 2 |
| *Liolaemus elongatus* | — | — | — | — | — | — | — | 7 | 3 | 52 |
| *Liolaemus kriegi* | — | — | — | — | — | — | — | — | 1 | 12 |
| *Liolaemus multiformis* | — | — | — | — | 16 | 4 | 7 | — | — | — |
| *Liolaemus ruibali* | — | — | — | — | — | — | — | 3 | — | — |
| *Phymaturus palluma* | — | — | — | — | — | — | — | 13 | — | — |
| *Proctoporus bolivianus* | — | — | — | 26 | — | — | — | — | — | — |
| *Proctoporus columbianus* | — | 1 | — | — | — | — | — | — | — | — |
| *Tachymenis peruvianus* | — | — | — | — | 1 | — | — | — | — | — |

## Appendix 3

Niche breadth values for species of amphibians and reptiles at the ten study sites. Letter designation of study sites correspond to those in Appendix 1. N = number of specimens used in the calculation of niche breadth and overlap; only those samples containing seven or more individuals are included. * = nocturnal species. Samples are ranked in descending order of overall niche breadth.

| Species (site) | N | Niche breadth: Structural habitat | Food | Overall |
|---|---|---|---|---|
| *Pleurodema marmorata* (E)* | 29 | 1.15 | 2.30 | 1.72 |
| *Liolaemus multiformis* (E) | 16 | 1.07 | 2.30 | 1.69 |
| *Liolaemus elongatus* (J) | 25 | 1.27 | 1.91 | 1.59 |
| *Pleurodema cinerea* (E)* | 9 | 0.94 | 1.97 | 1.46 |
| *Atelopus ebenoides* (B) | 65 | 0.61 | 2.22 | 1.42 |
| *Eleutherodactylus lynchi* (B)* | 91 | 0.32 | 2.49 | 1.41 |
| *Eleutherodactylus curtipes* (C)* | 83 | 0.22 | 2.52 | 1.37 |
| *Bufo spinulosus* (E)* | 28 | 1.00 | 1.71 | 1.35 |
| *Eleutherodactylus nicefori* (A)* | 21 | 0.38 | 2.33 | 1.35 |
| *Bolitoglossa adspersa* (B)* | 30 | 0.29 | 2.41 | 1.35 |
| *Liolaemus multiformis* (G) | 7 | 0.41 | 2.19 | 1.30 |
| *Liolaemus bibronii* (J) | 8 | 0.33 | 2.19 | 1.26 |
| *Colostethus subpunctatus* (B) | 76 | 0.72 | 1.75 | 1.23 |
| *Proctoporus bolivianus* (D) | 26 | 0.16 | 2.34 | 1.16 |
| *Gastrotheca marsupiata* (E)* | 7 | 0.60 | 1.58 | 1.15 |
| *Liolaemus kriegi* (J) | 11 | 1.13 | 1.11 | 1.12 |
| *Pleurodema marmorata* (G)* | 22 | 0.17 | 1.99 | 1.08 |
| *Gastrotheca excubitor* (D)* | 8 | 0.27 | 1.48 | 1.07 |
| *Homonota darwinii* (I)* | 22 | 0.18 | 1.91 | 1.05 |
| *Homonota darwinii* (J)* | 17 | 0.00 | 1.93 | 0.96 |
| *Telmatobius marmoratus* (F)* | 12 | 0.45 | 1.46 | 0.96 |
| *Telmatobius patagonicus* (J)* | 72 | 1.04 | 0.79 | 0.92 |
| *Pleurodema marmorata* (F)* | 65 | 0.06 | 1.77 | 0.92 |
| *Phrynopus peruvianus* (D)* | 12 | 0.29 | 1.48 | 0.87 |
| *Pleurodema bufonina* (J)* | 9 | 0.00 | 1.22 | 0.61 |
| *Liolaemus elongatus* (H) | 7 | 0.00 | 0.55 | 0.28 |
| *Phymaturus palluma* (H) | 13 | 0.72 | 0.00 | 0.14 |

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# Reproduction in the Mole Kingsnake, *Lampropeltis calligaster rhombomaculata* (Serpentes, Colubridae)

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ABSTRACT

The eggs and hatchlings of the mole kingsnake, *Lampropeltis calligaster rhombomaculata,* are described. Various aspects of reproduction are reported, including incubation time, copulation, and courtship behavior in which the female played the active role.

The mole kingsnake, *Lampropeltis calligaster rhombomaculata,* is a medium-sized form occupying a variety of habitats from Baltimore, Maryland, south through the Florida panhandle and west into Mississippi and Tennessee (Conant, 1975). This subspecies has been known for over 100 years, yet very little has been reported concerning reproduction, probably because of its secretive nature and infrequent collection.

Brimley (1943) noted that the eggs of this subspecies were much like those of other kingsnakes and remarked on their adherent nature, but he failed to give details concerning clutch and egg size. Grogan and Prince (1971) reported on a group of nine apparent hatchlings plowed up in Maryland on 27 August, and cited one additional reproductive record also from Maryland (Howden, 1946). Subsequent accounts have not provided reproductive data, although hatchlings and juveniles have been described and photographed (Conant, 1975; Mount, 1975). A moderate amount of data are available on the nominate form, *L. c. calligaster,* from much of its range (see Fitch, 1970, 1979; Wright and Wright, 1957, for a review). Nevertheless, this appears to be the first account describing copulation, egg-laying and hatching in *L. c. rhombomaculata.* Certain aspects of reproduction observed by us differ from previous accounts on colubrids and are noted.

Fig. 1. Adult specimens of *Lampropeltis calligaster rhombomaculata*.

## Materials and Methods

Two Georgia specimens from Clayton County were available (Fig. 1): a male (total length 894 mm, weight 260 g) received as an adult on 1 July 1976, and a captive-hatched (summer, 1975) female (total length 617 mm, weight 84.1 g after oviposition) received 4 April 1976.

The snakes were housed individually in various 1 or 2 ft fiberglass enclosures (Hulsey, 1973) both on and off exhibit at the Fort Worth Zoological Park, and were fed on laboratory mice. Temperatures varied from approximately 20°C in winter to 30°C in summer. Artificial lighting was provided by 30-watt Vita-lite® fluorescent tubes above the cages from 0800–1730 h daily. Clear skylights provided a natural photoperiod for the Fort Worth, Texas area.

The female was isolated prior to oviposition and provided with a nesting box filled with damp sphagnum moss. Eggs were measured with a vernier caliper, weighed on a triple-beam balance, and incubated in a vermiculite medium (Tryon, 1975) at 23–32°C. Adults and neonates were measured for snout-vent length and total length using the squeeze-box technique (Quinn and Jones, 1974). Copulation was recorded on 35 mm color transparencies.

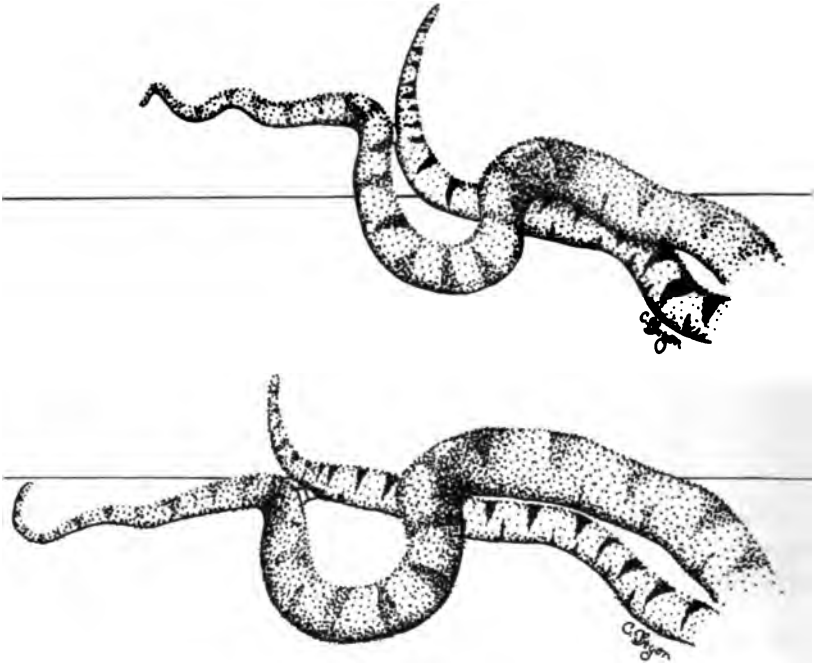

Fig. 2. Tail positions during copulation in *Lampropeltis calligaster rhombomaculata*. During initial observations, the male's tail was held horizontally as much as 2.5 cm above the substrate. The female's tail was held vertically throughout coital sequences. Horizontal line indicates substrate level.

## Results

The female was introduced for the first time into the male's enclosure on 12 February 1978. Initial reactions by both snakes included rapid (1 per sec) tongue flicking and body jerking.

Female ecdysis occurred on 18 April. On two occasions during the next seven days, she was seen lying on, and parallel to, the male's body. Although the male remained motionless, the female moved her cloacal region dorsally and dorsolaterally along the male's cloacal and tail regions. She exhibited occasional anterior jerking and tongue flicking. This behavior lasted 5–10 min, at which point she crawled slowly from the male and moved around the enclosure.

Although male courtship was not noted, the pair was observed *in copulo* at 1430 h and 1500 h, 26 and 27 April, respectively. The male's body was lying loosely on and parallel to the female's. Initially, his head rested on her nape, but moved during later observations. On both occasions, the only movement was intermittent waving and pulsating of the male's tail, which

was turned laterally and held in a horizontal plane on, or as much as 2.5 cm above, the substrate; the female's tail was held vertically (Fig. 2a, b). Tongue flicking, body jerking and biting were not noted. Observed copulatory durations were greater than 2 hours. Reproductive behavior was not seen after 27 April.

In 1979, the pair was observed *in copulo* on 21 April at 1545 hours. At this time, the male was lying in a superior position with a biting hold on the female dorsolaterally at the fifth anterior body blotch. This hold continued for at least one hour when observations were discontinued. The only movement was that of the tails as described above.

Oviposition occurred 2 June 1978 (5 eggs) and 7 June 1979 (13 eggs), 36 and 47 days after the last observed copulation, respectively. The eggs were white, elongate and strongly adherent. Egg length was 37–43 mm ($\bar{x}$ = 39.6 mm), diameter 14–17 mm ($\bar{x}$ = 16.0 mm) and clutch weight was 32.2 g ($\bar{x}$ egg wt. = 6.4 g) in 1978. In 1979, egg length was 27–34 mm ($\bar{x}$ = 29.7 mm), egg diameter 17–19 mm ($\bar{x}$ = 18.3 mm), and clutch weight was 74.7 g ($\bar{x}$ egg wt. = 5.7 g). Grand means for 18 eggs were 27–43 mm ($\bar{x}$ = 32.5 mm) in length, 14–19 mm ($\bar{x}$ = 12.6 mm) in diameter, and mean egg weight was 5.9 g. Clutch weight was 38% of the female's post-ovipositional weight in 1978.

The first egg was slit longitudinally 48 days after oviposition. Neonate snouts were exposed shortly after these slits appeared, and emergence occurred 12–24 h thereafter. Incubation periods ranged from 49–54 days for 17 eggs. One unslit egg in 1978 was opened and contained an undeveloped embryo. Total length and weight of the hatchlings was 193–236 mm ($\bar{x}$ = 220.7 mm) and 5.1–6.4 g ($\bar{x}$ = 5.5 g) (1978), and 210–230 mm ($\bar{x}$ = 219.5 mm) and 4.9–6.5 g ($\bar{x}$ = 5.8 g) (1979). Grand means for 17 hatchlings ranged from 193–236 mm ($\bar{x}$ = 219.8 mm) in total length, and weight ranged from 4.9–6.5 g ($\bar{x}$ = 5.8 g). Sex ratio for 17 hatchlings as determined by hemipenal eversion, was 11 males and six females. Tail length was 10.4–15.5% ($\bar{x}$ = 13.2%) of total length for 11 males and 11.0–13.0% ($\bar{x}$ = 12.1%) for six females. Mean total length of the hatchlings was 35% and 29% of the female parent's total length in consecutive years.

Coloration and pattern of the neonates (Fig. 3) was similar to previous descriptions of juvenile specimens (Conant, 1975; Mount, 1975); however, the neonates had an overall lavender ground-color with dark brown-red blotches until the first ecdysis, which occurred 7–10 days after hatching. At this time, ground color was a light brownish cream and blotches a deep red. Several specimens developed a light greenish tint anteriorly. The hatchlings fed readily on newborn mice and small lizards (*Scincella*).

## Discussion

Elements of reproduction observed by us in *L. calligaster rhombomaculata* corresponded in part to the general colubrid mating pattern de-

Fig. 3. Female parent and three-month-old juvenile *Lampropeltis calligaster rhombomaculata*. At four years of age, the female has retained the juvenile pattern.

scribed by Davis (1936). A recent survey of ritualized courtship and copulatory behavior in North American colubrid snakes did not include reference to *L. calligaster* (Murphy et al., 1978).

Of particular interest in our observations are those courtship sequences in which the female assumed what has been described (Davis, 1936; Gillingham et al., 1977; Murphy et al., 1978) as ritualistic male courtship posture. Although aberrant sexual behavior in snakes has been reviewed (Shaw, 1951; Bogert and Roth, 1966; Smith, 1968), reports such as ours are apparently non-existent. Bogert and Roth (1966) pointed out that aberrant behaviors are clearly captivity-dependent. Smith (1968), in discussing male homosexuality, stressed that although these matings may occur, they are the result of the captive snakes largely olfactory discriminatory powers being dulled and confused. He also noted that heterosexual combat or competitive displays have not been reported. However, Kennedy (1978) described a courtship pattern in a pair of *Lampropeltis getulus* in nature in which the participants rolled a short distance while completely entwined. His obser-

vations differ markedly from previously described colubrid courtship behavior. The pattern of intertwining more nearly fits that of male combat postures which have been recorded in other species of *Lampropeltis* (Murphy et al., 1978); therefore, the behavior observed by Kennedy may have been of a competitive rather than sexual nature.

Had the sexes of our *L. calligaster rhombomaculata* not been previously determined, the initial observations of courtship in the pair might have been recorded as normal ritualistic courtship in which the male plays the more active role. Female dominance may well have been a captivity-dependent aberrancy; however, female ecdysis occurred just prior to these observations and actual copulation was noted soon thereafter. Numerous accounts have indicated the importance of female ecdysis as a stimulus for the initiation of courtship in males at certain times of the year. Additionally, female receptivity is at a peak during these periods and may correspond with ovulation. Because the male did not display signs of courtship at female ecdysis, we believe the courtship behavior initiated by the female to be an active attempt to induce copulatory behavior. Although female snakes have traditionally been described as passive, or at least tolerant, during sexual encounters, additional observations may indicate a more active sexual role by females in snakes and other reptiles.

Reports of coital durations in the genus *Lampropeltis* have been 15 min in *L. getulus holbrooki* (Noble, 1937), 4–15 min for *L. mexicana alterna* (Murphy et al., 1978), about 15 min for *L. pyromelana woodini* (Martin, 1976) and an average of 20.6 min (25.0 min maximum) for *L. triangulum sinaloae* (Gillingham et al., 1977). Only Lewke's (1979) recent report of 4 h for *L. getulus* (*yumensis* phase) exceeds the coital durations of greater than 2 h reported herein for *L. calligaster rhombomaculata*.

Egg-laying in *L. c. calligaster* has been reported from 9 June–22 July for 10 clutches (Fitch, 1970; Iverson, 1975). Clutch sizes summarized by Fitch (1970) ranged from 6–17 ($\bar{x}$ = 11). Grogan and Prince (1971) estimated that their brood of 9 *L. c. rhombomaculata* were recently hatched on 27 August. Howden (1946) reported oviposition in this subspecies on 11 July in Maryland. The clutch of five reported herein is the smallest recorded for this species. This may be due to the smaller size of this subspecies (Conant, 1975), the small size of the female or the fact that it was the female's first clutch. Howden's (1946) clutch of 15 is the largest reported for this subspecies. The eggs and hatchlings of *L. c. rhombomaculata* average smaller in size and weight than those of the nominate form (Clarke, 1954; Fitch, 1979; Iverson, 1975; Shoop, 1957).

It is of interest that our female, although sexually mature, has fully retained the characteristic juvenile pattern (Fig. 1). D. W. Herman (pers. comm.) examined a number of specimens from Clayton and south Fulton counties, Georgia and found this to be a frequent occurrence in these pop-

ulations. Further observations in nature and of maturing specimens may indicate pattern retention to be a sexually dimorphic character.

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## Literature Cited

Bogert, C. M., and V. D. Roth. 1966. Ritualistic combat of male gopher snakes, *Pituophis melanoleucus affinis* (Reptilia, Colubridae). Am. Mus. Novit. 2245:1–27.

Brimley, C. S. 1943. The amphibians and reptiles of North Carolina. Raleigh. Carolina Tips.

Clarke, R. F. 1954. Eggs and egg-laying of *Lampropeltis c. calligaster* (Harlan). Herpetologica 10(1):15–16.

Conant, R. 1975. A field guide to reptiles and amphibians of eastern and central North America. 2nd ed.; Houghton Mifflin Co., Boston. 429 pp.

Davis, D. D. 1936. Courtship and mating behavior in snakes. Field Mus. Nat. Hist. Publ. Zool. Ser. 20:257–290.

Fitch, H. S. 1970. Reproductive cycles in lizards and snakes. Univ. Kans. Publ. Mus. Nat. Hist. Misc. Publ. No. 52:1–247.

Fitch, H. S. 1979. A field study of the prairie kingsnake (*Lampropeltis calligaster*). Trans. Kansas Acad. Sci. 81(4):353–363.

Gillingham, J. C., C. C. Carpenter, B. J. Brecke, and J. B. Murphy. 1977. Courtship and copulatory behavior of the Mexican milksnake, *Lampropeltis triangulum sinaloae* (Colubridae). Southwest. Nat. 22:187–194.

Grogan, W. L., Jr., and E. C. Prince. 1971. Notes on hatchling mole snakes, *Lampropeltis calligaster rhombomaculata* (Holbrook), in Maryland. Bull. Maryland Herp. Soc. 7(2):42.

Howden, H. F. 1946. The brown king snake or mole snake *Lampropeltis rhombomaculata* in Maryland. Maryland J. Nat. Hist. 16(2):38–40.

Hulsey, T. G. 1973. Fiberglas reptile cages at the Fort Worth Zoo. Hiss News-J. 1(3):93–94.

Iverson, J. B. 1975. Notes on Nebraska reptiles. Trans. Kans. Acad. Sci. 78(1/2):51–62.

Kennedy, J. L. 1978. Field observations on courtship and copulation in the eastern king snake and the four-lined rat snake. Herpetologica 34:51–52.

Lewke, R. E. 1979. Neck biting and other aspects of reproductive biology of the Yuma kingsnake (*Lampropeltis getulus*). Herpetologica 35:154–157.

Martin, B. E. 1976. Notes on breeding behavior in a captive pair of Sonora mountain kingsnakes (*Lampropeltis pyromelana*). Bull. Maryland Herp. Soc. 12(1):23–24.

Mount, R. H. 1975. Reptiles and amphibians of Alabama. Agricultural Experimental Station, Auburn University, 345 pp.

Murphy, J. B., B. W. Tryon, and B. J. Brecke. 1978. An inventory of reproduction and social behavior in captive gray-banded kingsnakes, *Lampropeltis mexicana alterna* (Brown). Herpetologica 34(1):84–93.

Noble, G. K. 1937. The sense organs involved in the courtship of *Storeria*, *Thamnophis* and other snakes. Bull. Am. Mus. Nat. Hist. 73(7):673–725.

Quinn, H., and J. P. Jones. 1974. Squeeze box technique for measuring snakes. Herpetol. Rev. 5(2):35.

Shaw, C. E. 1951. Male combat in American colubrid snakes with remarks on combat in other colubrid and elapid snakes. Herpetologica 7:149–168.

Shoop, R. 1957. Eggs and young of the prairie kingsnake, *Lampropeltis c. calligaster*. Copeia 1957:48–49.

Smith, H. M. 1968. Heterecious sexual behavior versus homosexuality in snakes. J. Herpetol. 2:162–163.

Tryon, B. W. 1975. How to incubate reptile eggs: a proven technique. Bull. N. Y. Herp. Soc. 11:33–37.

Wright, A. H., and A. A. Wright. 1957. Handbook of snakes of the United States and Canada. Vol. 1. Comstock Publ. Assoc., Ithaca, 564 pp.

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# Distributional Records for Three Species of Mammals in Kansas

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ABSTRACT

Breeding *Nycticeius humeralis* and nursery colonies of *Tadarida brasiliensis* in southern Kansas are reported, and the occurrence of *Glaucomys volans* beyond the western limit of the eastern deciduous forest is documented.

Renewed interest in biogeographic and systematic relationships of mammals on the central Great Plains has resulted in accumulation of additional data on past and present distributions of mammals in Kansas (for example, Choate and Fleharty, 1975; Choate and Williams, 1978). The purpose of this report is to place on record unpublished information for three species whose known distributions terminate in Kansas. Most of the specimens on which this report is based were gathered while one of us (Kunz) was affiliated with the State Biological Survey of Kansas.

## *Nycticeius humeralis humeralis*

Birney and Rising (1967:522–523) summarized the distributional status of the evening bat in Iowa, Nebraska, and Kansas. Included in their account was the report of a pregnant female obtained in Ford County, Kansas, "approximately 200 miles southwest of the nearest previously reported locality . . . ," which thereby documented the westernmost known occurrence of the species in the United States. Glass and Humphrey (1971) subsequently reported additional records of the evening bat in Oklahoma, and Czaplewski et al. (1979) reviewed the distribution of this species in Nebraska.

On 30 June 1969, four lactating females were shot (by Kunz) at a place 2½ mi S and 1¼ mi E Medicine Lodge, Barber County, as they flew (with other bats assumed to be *N. humeralis*) along the South Fork of the Med-

icine River. The bats were foraging intermittently at treetop level and occasionally dipping toward the surface of the river. Large cottonwood (*Populus deltoides*), hackberry (*Celtis reticulata*), and willow (*Salix* sp.) trees were growing in clusters along the floodplain. The next day (1 July) each building within a two-mile radius of the place where the bats were shot was investigated, but no bats (including other species which are known from Barber County and which frequently occupy buildings) were found. The absence of evening bats in nearby buildings, their sudden appearance at dusk, and the abundance of mature trees on the floodplain suggest that nursery colonies were situated in the trees.

On 10 July 1969, a juvenal female was shot as it foraged adjacent to riparian vegetation near Mule Creek, ½ mi S and 1 mi W Wilmore, Comanche County. Here, too, large cottonwood trees provided potential roosts. At the same locality an adult male *Lasiurus borealis* and two lactating female *Myotis velifer* were shot; the latter species was expected owing to the presence of a large nursery roost nearby (Kunz, 1973), but neither of the other species was. Buildings in the vicinity were examined, but no evening bats were found. Bat traps and nets set along Mule Creek and at entrances to nearby roosts of *M. velifer* in the summers of 1969 and 1970 failed to produce additional specimens of *N. humeralis*. The fact that a young evening bat was fledged successfully in Comanche County documents the reproductive success of this species in riparian habitats near the semi-arid, western margin of its geographic range.

An additional evening bat obtained at Larned, Pawnee County, is further evidence for the presence of this species throughout much of western Kansas. The circumstances under which it was taken are unknown. The above-mentioned specimens are deposited in the Museum of Natural History at The University of Kansas.

### *Tadarida brasiliensis mexicana*

Conflicting statements have been made regarding the summer occurrence and reproductive status of the Brasilian free-tailed bat in Kansas. This species apparently inhabited several buildings in Medicine Lodge, Barber County, in the early part of this century (Hibbard, 1936) and, at the time of Cockrum's (1952) report, these represented the only known summer colonies in the state. Jones et al. (1967:25–27) knew of no permanent colonies in Kansas, and apparently were unaware of the status of the aforementioned colonies in Medicine Lodge. Barbour and Davis (1969:198–199) assumed that "Records from throughout Kansas probably represent wanderers from the great colonies in Oklahoma caves."

As recently as the summer of 1970, a nursery colony was present in at least one building in Medicine Lodge. Other colonies reported by Hibbard

(1936) have been exterminated or the buildings they occupied have been demolished. In the autumn of 1968, the attic of the Medicine Lodge Hotel was renovated and the remaining bats were eliminated. According to the owner at that time, several bags of guano were removed from the building. In March of 1969, one of us (Kunz) was informed of another colony in the attic of a building adjacent to the Masonic Hall in Medicine Lodge. The presence of approximately 30 free-tailed bats and the accumulation of a considerable quantity of guano suggested that this building had been regularly occupied by bats for several years. This colony was visited periodically during the summers of 1969 and 1970, and it was noted that the population was at its maximal density (about 2000) in June. Young were born in June and early July, and by early September most bats had vacated the building. No adult males were observed. To our knowledge, this building represents the northeasternmost location of a breeding colony for *T. brasiliensis*.

According to a former owner (now deceased) of the building, numerous unsuccessful attempts had been made to exterminate these bats by means of moth crystals and lighted sulfur candles. It is not known whether or not the present owner has attempted to exterminate the bats, and, at this writing (November 1979), the status of the colony is unknown.

Another likely colony was discovered, on 24 November 1971, in an old building in Protection, Comanche County, by personnel from the Museum of the High Plains, Fort Hays State University. Although no live bats were found, numerous mummified remains of free-tailed bats (together with those of cave bats, *Myotis velifer*) and an appreciable quantity of guano indicated that this might represent a breeding colony. Its present status is unknown. The abovementioned specimens are deposited in the Museum of Natural History at The University of Kansas.

### *Glaucomys volans volans*

As noted by Cockrum (1952), the southern flying squirrel is rare in Kansas and is known only from forested regions along the eastern border of the state. However, in May of 1965 an immature male was trapped by David E. Loyle in a grove of cottonwood trees and dense brush along Whitewater Creek, approximately 1½ mi N Greenwich, Sedgwick County. The owner of the property on which the squirrel was trapped had been a resident of the area for nearly 70 years, and had not noticed flying squirrels until the early 1960s (D. A. Distler, pers. comm.). This specimen documents an approximately 90-mile westward extension of the known distribution of the southern flying squirrel in Kansas, and represents the first locality of record for the species beyond the western limit of the eastern deciduous forest.

The flying squirrel (preserved in alcohol) was examined by one of us (Kunz) and is deposited in the collection of mammals at Wichita State Uni-

versity. We thank Donald A. Distler for making this specimen available for examination.

## Literature Cited

Barbour, R. W., and W. H. Davis. 1969. Bats of America. Univ. Press Kentucky, Lexington, 286 pp.

Birney, E. C., and J. D. Rising. 1968. Notes on distribution and reproduction of some bats from Kansas, with remarks on incidence of rabies. Trans. Kansas Acad. Sci. 70:519–524.

Choate, J. R., and E. D. Fleharty. 1975. Synopsis of native, Recent mammals of Ellis County, Kansas. Occas. Papers Mus., Texas Tech Univ. 37:1–80.

Choate, J. R., and S. L. Williams. 1978. Biogeographic interpretation of variation within and among populations of the prairie vole, Microtus ochrogaster. Occas. Papers Mus., Texas Tech Univ. 49:1–25.

Cockrum, E. L. 1952. Mammals of Kansas. Univ. Kansas Publ., Mus. Nat. Hist. 7:1–303.

Czaplewski, N. J., J. P. Farney, J. K. Jones, Jr., and J. D. Druecker. 1979. Synopsis of bats of Nebraska. Occas. Papers Mus., Texas Tech Univ. 61:1–24.

Glass, B. P., and S. R. Humphrey. 1971. Distribution of the evening bat, *Nycticeius humeralis*, in Oklahoma. Southwestern Nat. 15:399–400.

Hibbard, C. W. 1936. Established colonies of the Mexican free-tailed bat in Kansas. J. Mamm. 17:167–168.

Jones, J. K., Jr., E. D. Fleharty, and P. B. Dunnigan. 1967. The distributional status of bats in Kansas. Misc. Publ. Mus. Nat. Hist., Univ. Kansas 46:1–33.

Kunz, T. H. 1973. Population studies of the cave bat (*Myotis velifer*): reproduction, growth, and development. Occas. Papers Mus. Nat. Hist., Univ. Kansas 15:1–43.

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# Effects of Intense, Short-term Traffic on Soil Physical Properties and Turfgrass Growth[1]

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## ABSTRACT

Most turfgrass areas are subjected to some degree of traffic resulting in wear and compaction stresses on the plant. Along with physical abrasion caused by wear, traffic causes compaction which presses soil particles together altering soil physical parameters. With a constant force, the degree of compaction is a function of soil water content.

Five treatments were applied to a 2.5-year-old tall fescue (*Festuca arundinacea* Schreb. 'Kentucky 31') stand on a Chase silty clay loam. A one-time compaction treatment of 35 passes with a water filled, smooth, power roller exerting 1.0 kg/cm$^2$ static pressure, was applied to a soil with four soil moisture levels. Soil moisture treatments were established by irrigating the area until water was standing and then applying the compaction treatment 0, 4, 24, and 72-hours after the standing water condition, respectively. The fifth treatment was a non-compacted check. The effects of treatments on soil physical factors and plant growth were monitored. The study took place from 3 May to 11 July 1979.

Of the compacted treatments, bulk density was 1.41 g/cm$^3$ for the 24-hour treatment and 1.31 g/cm$^3$ for both the 0-hour treatment and the check. Aeration porosity at $-0.1$ bar matric potential was reduced by 20% for the soil compacted at saturation compared to the check.

Two and six weeks after treatment date, visual ratings were reduced in all compacted plots. A correlation coefficient of 0.82 occurred between visual quality and aeration porosity at $-0.1$ bar matric potential. No verdure and shoot density differences were found between treatments. Four weeks after treatment, root weights at the 0–10 cm level were reduced by 39% in the saturated treatment compared to the uncompacted check.

Total nonstructural carbohydrate (TNC) levels 4 weeks after compaction were higher than the check for the 0, 4, and 24-hour treatments, possibly

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indicating better soil moisture relations. By 9 weeks after compaction, all treatments exhibited similar TNC levels.

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Most turfgrass areas are subjected to some degree of traffic which is a stress on the turfgrass plant. Even routine maintenance practices, such as mowing, impose traffic stress. Recreational turfs may deteriorate if subjected to heavy traffic when environmental and soil conditions are unfavorable.

The two major problems related to traffic are wear and soil compaction. Wear is the injurious effects of concentrated traffic on a turf due to physical abrasion and tearing (Beard, 1973). Compaction is the pressing together of soil particles into a more dense soil mass (Beard, 1973; Madison, 1971), which influences air, water, and soil strength factors. These factors in turn affect growth and persistence of the turf (Taylor and Blake, 1979).

There is an optimum moisture content at which soil compacts to the greatest extent when exposed to a constant applied force (Harris, 1971). Due to the incompressibility of water in a saturated soil, maximum compaction will occur at some point after the larger pores start to drain and fill with air. At that time water will act as a lubricant allowing soil particles to pack closer together (Madison, 1971).

While the influence of soil moisture content on soil compactibility has been known for many years, literature pertaining to turfgrass response to compacting forces at different moisture levels is scarce. Data in this area would be beneficial to turf managers making decisions concerning traffic control on recreational turf sites.

The objective of this study was to observe the effects of intense, short-term traffic at different soil moisture levels on soil physical properties and turfgrass growth.

## Materials and Methods

To observe the effects of heavy traffic on an established turf at different soil moisture levels, five treatments were applied to a 2.5-year-old tall fescue (*Festuca arundinacea* Schreb., 'Kentucky 31') stand. The soil was a Chase silty clay loam of the fine, montmorillonitic, mesic Aquic Arguidolls at the Kansas State University Turf Research Plots in Manhattan, Kansas. The study was done from 4 May to 11 July 1979. Plots measured 2.44 × 1.13 m and were separated by .61 m alleys. Treatments were replicated three times in a completely randomized design.

All compaction treatments were initiated on 4 May. Four of the treatments were compacted at: 0 (saturation); 4 (partially saturated); 24 (field capacity); and 72 (below field capacity) hours after irrigating the total area to a standing

Table 1. Water content at treatment, bulk density, and aeration porosity.

| Soil moisture treatment by time | Moisture content at treatment | | Bulk density | | Aeration porosity | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | −0.10 bar | | −0.33 bar | |
| | % by vol. | Matric potential | 20 May | 20 June | 20 May | 20 June | 20 May | 20 June |
| | | bar | gm/cm³ | | % | | | |
| 0-hour (saturation) | 46.2a† | −.07 | 1.33ab | 1.31c | 16.1b | 18.4a | 19.2b | 23.2b |
| 4-hour (part. sat.) | 42.6b | −.09 | 1.35a | 1.34bc | 19.0a | 21.7a | 22.5a | 26.9a |
| 24-hour (field cap.) | 40.0c | −.12 | 1.35a | 1.41a | 18.8a | 19.8a | 22.4a | 24.4ab |
| 72-hour (below f.c.) | 31.9d | −2.00 | 1.34a | 1.37ab | 19.4a | 21.9a | 23.1a | 26.5ab |
| Checked (uncompacted) | — | — | 1.28ab | 1.31c | 20.3a | 21.5a | 24.0a | 25.1ab |

† Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

water condition. The fifth treatment received no compaction and served as a check.

All compaction treatments were applied by using 35 passes per area with a water filled, smooth power roller. Static pressure was 1.0 kg/cm². A smooth roller was used to reduce wear.

Soil samples, three from each plot, were taken immediately before each compaction treatment to determine soil water content for each moisture level treatment. Soil moisture contents for all samples were determined gravimetrically (Table 1).

Normal mowing practices with a three-gang self-propelled reel mower were continued. Two weeks prior to treatment, all plots received 0.48 kg N/100 m². No irrigation was applied, while rainfall over the period of the study totaled 16.2 cm.

Three undisturbed soil cores (5.4 cm I.D. × 3 cm) per plot, were taken 2 and 6 weeks after the last treatment. These cores were used to determine bulk density (Blake, 1965), porosity (Vomocil, 1965), and moisture retention (Richards, 1965).

Samples for percent total nonstructural carbohydrates (TNC) were taken from each plot before 10 a.m. with a 5.7 cm I.D. plugger. Live shoot tissue was excised from the plugs, combined, and dried at 100°C for 1 hour, then 60°C for 24 hours. TNC was determined with Dreywood's anthrone reagent (Morris, 1948).

Verdure (Madison, 1962) and shoot density were determined at the same time as the second and third TNC samples were taken. Shoot density was obtained by removing two 5.7 cm I.D. plugs from each plot and counting the number of actively growing shoots.

Root weight samples were taken 6 and 9 weeks after the last treatment

Table 2. Moisture retention by volume.

| | Percent water content by volume at four matric potentials | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 bar | | −0.10 bar | | −0.33 bar | | −1.0 bar | |
| Treatment | 20 May | 20 June | 20 May | 20 June | 20 May | 20 June | 20 May | 20 June |
| | % | | | | | | | |
| 0-hour | 59.2b† | 62.0a | 43.1a | 43.6a | 40.0a | 38.8a | 38.4a | 36.2a |
| 4-hour | 61.8a | 64.9a | 42.8a | 43.2ab | 39.3a | 38.0a | 37.8a | 35.2ab |
| 24-hour | 61.3a | 63.1a | 42.5a | 43.3ab | 39.0ab | 38.6a | 37.4a | 35.8ab |
| 72-hour | 61.9a | 64.3a | 42.4a | 42.4ab | 38.7ab | 37.9a | 37.1ab | 34.9b |
| Check | 61.5a | 63.6a | 41.2a | 42.1b | 37.5b | 38.5a | 35.6b | 34.9b |

† Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

with four cores (2 cm I.D. × 20 cm) per plot. Samples from each plot were combined, washed, dried at 60°C for 24 hours and weighed.

## Results and Discussion

### Soil Physical Properties

Based on the moisture retention curve for the uncompacted check, moisture retention at the time of compaction was −0.07, −0.09, −0.16, and −2.0 bar matric potential for the 0, 4, 24, and 72-hour treatments, respectively. While the saturation (0-hour) treatment was apparently not saturated to a depth of 3 cm, the surface was saturated as evidenced by standing water. This treatment also exhibited the lowest bulk density for all compacted treatments (Table 1).

*Bulk density.* Harris (1971) and Madison (1971) noted that the degree of compaction, as expressed by bulk density, was a function of moisture content at a constant pressure. Maximum compaction occurs near field capacity when air filled pores can be compressed and sufficient moisture acts as a lubricant. This trend was apparent with the greatest increase in bulk density occurring at the 24-hour treatment followed by the 72, 4, and 0-hour treatments (Table 1). Bulk densities were 1.31 and 1.41 g/cm$^3$ for the check and 24-hour treatment, respectively on 20 June.

*Porosity and moisture retention.* Compaction may alter the pore-size distribution and, consequently, aeration and moisture relationships are affected (Van Wijk et al., 1977; Warkentin, 1971). When compaction was applied to the saturated soil, reductions of 3.7% in total porosity (Table 2) and 20% in aeration porosity at −0.10 bar (Table 1) compared to the check were observed.

Hillel (1971) noted that soil structure affects the soil moisture character-

Table 3. Visual quality ratings.

| Treatment | Visual quality ratings‡ | | | | |
|---|---|---|---|---|---|
| | 4 May | 20 May | 6 June | 20 June | 9 July |
| 0-hour | 7.2a† | 5.3d | 6.3a | 5.7b | 5.7b |
| 4-hour | 6.7a | 6.3bc | 6.0a | 5.7b | 6.2ab |
| 24-hour | 6.8a | 6.0c | 6.2a | 5.7b | 6.0b |
| 72-hour | 6.7a | 6.5b | 6.0a | 5.8ab | 6.3ab |
| Check | 7.0a | 7.0a | 6.5a | 6.3a | 6.8a |

† Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

‡ Visual quality ratings are based on shoot density, color, and uniformity with 9 = ideal turf, 1 = no live turf.

istic curve in the low-suction range and that compaction decreases total porosity and the size of large interaggregate pores. The reduction of aeration porosity of the compacted saturated soil indicates that porosity was affected by changes in soil structure.

At 0 bar matric potential, moisture retention for the 0-hour treatment was lower than the check on 20 May. The saturated treatment also showed a higher moisture retention at −1.0 bar than the check (Table 2). The decrease at the 0 bar with an increase at −1.0 bar matric potential indicates a change in pore-size distribution.

## Plant Growth

*Visual ratings.* On 4 May prior to compaction, all plots demonstrated similar visual quality (Table 3). Two weeks after treatment, compacted plots exhibited decreased visual quality, particularly the 0-hour treatment. Part of the reduction in quality for the 0-hour plots was due to mud collected on the leaves after the power roller treatment.

During the first half of June, weather conditions were moist with generally moderate temperatures favorable for tall fescue growth. Similar visual quality ratings were noted for this period. By 20 June, after a week of high temperatures and heavy rainfall, visual quality differences were again apparent. Plots receiving the 0- and 24-hour treatments tended to demonstrate the greatest reduction in quality.

*Verdure and shoot density.* No differences between treatments at either sampling date were evident for verdure and shoot density (Table 4). These are often related to visual quality which is based on shoot density, color and uniformity. However, in this study, they were not well correlated; correlation coefficients were 0.34, 0.17, and 0.37 for quality-density, quality-verdure, and density-verdure relationships, respectively. Turf quality was a

Table 4. Verdure and shoot density.

| Treatment | Verdure | | Shoot density | |
|---|---|---|---|---|
| | 6 June | 20 June | 6 June | 20 June |
| | mg/100 cm² | | no./100 cm² | |
| 0-hour | 1326.1a† | 1426.6a | 15.4a | 14.4a |
| 4-hour | 1400.0a | 1526.6a | 21.6a | 20.4a |
| 24-hour | 1173.4a | 1293.4a | 15.8a | 14.6a |
| 72-hour | 1386.6a | 1606.6a | 16.6a | 23.2a |
| Check | 1440.0a | 1380.0a | 22.6a | 19.6a |

† Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

good indicator of compaction effects as illustrated by a correlation coefficient of 0.82 for quality versus aeration porosity at −0.1 bar.

*Root weights.* At 4 weeks after compaction, root density at the 0–10 cm level for the 0-hour treatment was only 61% of the uncompacted check (Table 5). Even though differences were not significant, the turf in the 2, 24, and 72-hour treatments exhibited a trend of decreased root development. By 10 weeks, no significant differences in root density were evident among treatments.

Tall fescue is a cool season grass that exhibits root growth primarily in the spring and fall. Restriction of new root initiation in the spring by compaction could result in a shallow root system during the hot summer months when drought stress is severe.

Other investigators have noted that a relationship exists between degree of compaction, aeration porosity, bulk density, and root growth (Flocker and Menary, 1960; Swartz and Kardos, 1963; Taylor and Blake, 1979; Thur-

Table 5. Root weights.

| Treatment | Root weights by depth | | | |
|---|---|---|---|---|
| | 6 June | | 9 July | |
| | 0–10 cm | 10–20 cm | 0–10 cm | 10–20 cm |
| | mg/100 cm³ | | | |
| 0-hour | 508.0b† | 201.0a | 649.6a | 169.2a |
| 4-hour | 644.6ab | 256.0a | 684.2a | 203.8a |
| 24-hour | 713.4a | 250.0a | 612.4a | 169.2a |
| 72-hour | 727.0a | 191.8a | 705.6a | 177.4a |
| Check | 831.4a | 284.6a | 744.6a | 186.8a |

† Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

Table 6. Total nonstructural carbohydrates.

| Treatment | 16 May | 6 June | 20 June | 9 July |
|---|---|---|---|---|
| | % | | | |
| 0-hour | 7.7bt | 19.0b | 25.7a | 24.7a |
| 4-hour | 11.3ab | 20.0b | 26.3a | 27.3a |
| 24-hour | 12.7a | 25.7a | 17.7b | 20.7a |
| 72-hour | 10.3ab | 13.0c | 17.7b | 24.0a |
| Check | 13.4a | 17.0bc | 25.0a | 22.3a |

† Numbers within columns not followed by the same letter differ at the 0.10 level of probability using Duncan's Multiple Range Test.

man and Pokorny, 1969; Wilkinson and Duff, 1972). However, correlation analyses were not given indicating the degree of correlation and significance among these parameters. Correlation analysis revealed correlations of 0.70 and −0.46 for aeration porosity at −1.0 bar matric potential and bulk density versus root density at the 0–10 cm level, respectively.

*Total nonstructural carbohydrates.* TNC levels are an indicator of reserve carbohydrates necessary for regrowth and recovery should the turf be injured by environmental stresses, pests, or human activities. Also, carbohydrate reserves are utilized by the plant for growth. TNC levels are normally highest during periods of limited shoot growth (Beard, 1973).

Only the 0-hour treatment exhibited a reduced TNC level 2 weeks after compaction (Table 6) and may have been a result of mud on the leaves for several days blocking incident radiation for photosynthesis. The 0, 4, and 24-hour treatments exhibited higher TNC levels than the check 4 weeks after compaction. Since 2.5 cm rainfall on 16 May accounted for all the precipitation until 9 June, slightly greater moisture retention in the 0, 4, and 24-hour treatments may have allowed better moisture relationships.

TNC levels increased from 6 June until 20 June, except for the 24-hour treatment which had a 35% decrease. The reason for this was not apparent from the data in this study. By 9 July TNC levels were similar for all plots.

The 72-hour treatment (below field capacity) exhibited the lowest TNC levels at the 6 June and 20 June dates. Soil physical characteristics measured in the study did not indicate the reason for this response. Since physical abrasion (wear) of the leaf tissue should be greater under drier conditions. perhaps some physical damage to leaf and shoot tissues resulted from compaction.

## Conclusion

Many recreational turf stands are subjected to repeated, heavy traffic. In this study intense traffic was applied only for a short period and wear was

minimized. Thus much greater influence on soil physical properties and turf growth would be expected under normal recreational use. This study does illustrate that turf sites subjected to heavy traffic for short periods are adversely affected, especially when the soil is saturated or near field capacity. Turf deterioration from these treatments was still evident 9 weeks after compaction. Athletic field managers should schedule irrigation and site use to minimize traffic when the moisture content is at field capacity or greater.

## Literature Cited

Beard, J. B. 1973. Turfgrass: science and culture. Prentice-Hall Inc., Englewood, N.J.

Blake, C. R. 1965. Bulk density. Pp. 374–390. In C. A. Black (ed.) Methods of soil analysis. Part I. Am. Soc. Agron., Madison, Wis.

Flocker, W. J., and R. C. Menary. 1960. Some physiological responses in two tomato varieties associated with levels of soil bulk density. Hilgardia 30:101–121.

Harris, W. L. 1971. The soil compaction process. Pp. 9–46. In K. K. Barnes, W. M. Carleton, H. M. Taylor, R. I. Throckmorton, and G. E. Vanden Berg (eds.). Compaction of agricultural soils. ASAE, St. Joseph, Mich.

Hillel, D. 1971. Soil and water physical principles and processes. Academic Press, New York.

Madison, J. H. 1962. Turfgrass ecology. Effects of mowing, irrigation, and nitrogen treatments of *Agrostis palustris* Huds., 'Seaside' and *Agrostis tenuis* Sebth., 'Highland' on population yield, rooting and cover. Agron. J. 55:461–465.

Madison, J. H. 1971. Principles of turfgrass culture. Van Nostrand Rienhold Co., New York.

Morris, D. L. 1948. Quantitative determination of carbohydrates with Dreywood's anthrone reagent. Science 107:254–255.

Richards, L. A. 1965. Physical conditions of water in soil. p. 128–152. In C. A. Black (ed.). Methods of soil analysis, Part I. Am. Soc. Agron., Madison, Wis.

Swartz, W. E., and L. T. Kardos. 1963. Effects of compaction on physical properties of sand-soil-peat mixtures at various moisture contents. Agron. J. 55:7–10.

Taylor, D. H., and G. R. Blake. 1979. Sand content of sand-soil-peat mixtures for turfgrass. Soil Sci. Soc. of Amer. Jour. 43:394–398.

Thurman, P. C., and F. A. Pokorny. 1969. The relationship of several amended soils and compaction rates on vegetative growth, root development and cold resistance of Tifgreen bermudagrass. J. Amer. Soc. Hort. Sci. 94:463–465.

Van Wijk, A. L. M., W. B. Verhaegh, and J. Beuving. 1977. Grass sportsfields: toplayer compaction and soil aeration. Rasen, Turf, Gazon 8:47–52.

Vomocil, J. A. 1965. Porosity. Pp. 299–314. In C. A. Black (ed.). Methods of soil analysis. Part I. Am. Soc. Agron., Madison, Wis.

Warkentin, B. P. 1971. Effects of compaction on content and transmission of water in soils. Pp. 126–153. In K. K. Barnes, W. M. Carleton, H. M. Taylor, R. I. Throckmorton, and G. E. Vanden Berg (eds.). Compaction of agricultural soils. ASAE, St. Joseph, Mich.

Wilkinson, J. F., and D. T. Duff. 1972. Rooting of *Poa annua* L., *Poa pratensis* L. and *Agrostis palustris* Huds. at three soil bulk densities. Agron. J. 64:66–68.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
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# Effect of Nitrogen Solution on the Germination of Shattercane[1]

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ABSTRACT

Shattercane is a serious weed problem for many Kansas farmers. After reports that liquid nitrogen solution (urea ammonium nitrate) applied during late fall reduced shattercane infestations, two experiments were conducted to determine the potential of that practice for controlling shattercane. Nitrogen rates of 0, 110, 220, and 440 kg N/ha were applied to samples of shattercane seeds that were then allowed to remain under natural conditions up to 150 days. Shattercane emergence was not affected by nitrogen rates through 220 kg N/ha, so rates in a second trial were 0, 220, 440, and 660 kg N/ha and the seed samples then were stored at −10 C, 3 C, or 29 C. Seed germination was reduced but only the 660 kg N/ha rate gave valuable reduction, so nitrogen solution applied at normal rates (220 kg N/ha or less) would not be expected to effectively reduce shattercane stands.

Shattercane (*Sorghum bicolor* (L.) Moench), also known as wild cane and black amber, is a serious weed in many corn, soybean, and sorghum fields. It probably is the result of natural crossing of diverse sorghum types within cultivated sorghum. The name "shattercane" comes from the characteristic early shattering of the seed before the cultivated crop is harvested. Crop yield losses of 40% under natural conditions (Burnside, 1973) and up to 95% under controlled conditions (Vesecky et al., 1973) have been reported. Shattercane seed has been reported to remain viable under field conditions for three to ten years (Burnside, 1965; Nilson, 1970; and Jacques et al., 1974). Casual observations indicated that when shattercane infested fields were fertilized with urea-ammonium nitrate (UAN) solutions during late fall shattercane infestation the following spring was reduced. This could be due either to direct reduction in germination because of the nitrogen or because of reduced dormancy of the seed resulting in fall germination and winter killing of the seedlings. Nitrogen placed directly with sorghum seed has

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been shown to decrease stands by 36 and 78 percent under good and limited surface soil moisture conditions, respectively (Thompson, 1974). Germination of shattercane seed was 53, 84, and 90 percent at 3 days, 5 and 12 months after seed harvest, respectively, indicating the presence of dormancy immediately after harvest (Burnside, 1973). Nitrate solutions have been used to promote germination of dormant seeds (Toole et al., 1956). Treatment with potassium nitrate was shown to double the percent germination of Johnson grass (*Sorghum halepenses*) (Taylorson and McWhorter, 1968). Field applications of nitrogenous fertilizers have also been shown to hasten emergence of wild oats, thereby increasing the possibility of control through early cultivation (Watkins, 1966; Sexsmith and Pittman, 1963). The objective of this study was to determine if applications of liquid nitrogen (UAN) could be used to assist in controlling shattercane.

## Materials and Methods

*Experiment 1.* One hundred shattercane seeds were placed on the soil surface in plastic cups on 3 November 1972. On 10 November a urea-ammonium nitrate (UAN) solution was sprayed on the surface of the soil at rates of 0, 110, 220, and 440 kg N/ha and immediately worked into the soil in half of the cups to simulate a tillage operation. Cups containing the seed were allowed to remain in the field and 3 replicates of each treatment taken in for determination of emergence under favorable growing conditions 0, 7, 30, and 150 days after nitrogen application.

*Experiment 2.* Nitrogen (UAN) rates of 0, 220, 440, and 660 kg N/ha were applied to shattercane seed and the seed then stored at three temperatures, −10 C, 3 C, and 29 C. Triplicate 100-seed samples were germinated according to standard germination procedures at 0, 7, 21, 35, 49, and 63 days after nitrogen application.

## Results and Discussion

Shattercane emergence was not affected by UAN nitrogen rates up through 220 kg N/ha (Table 1). The 440 kg N/ha rate resulted in significant

Table 1. Effect of nitrogen rate on shattercane emergence.

| N rate, kg/ha | % Emergence |
|---|---|
| 0 | 32.4 |
| 110 | 33.9 |
| 220 | 30.0 |
| 440 | 25.9 |
| LSD (.05) | 7.4 |

Table 2. Effects of tillage and time after nitrogen application on shattercane emergence.

| Days after application | % Emergence | |
|---|---|---|
| | Tilled | Not tilled |
| 0 | 45.9 | 41.1 |
| 7 | 37.6 | 43.2 |
| 30 | 26.8 | 38.4 |
| 150 | 4.7 | 6.7 |
| LSD (.05) | 7.9 | |

reduction in percent emergence as compared to the 110 kg N/ha rate (Table 2). Effect of tillage on shattercane emergence depended upon the time after application of the nitrogen solution. Where the soil was tilled, each succeeding sampling date showed a significant reduction in percent shattercane emergence. Where the soil was not tilled there was no change in percent emergence through the first 30 days following application. The extremely low emergence figures for 150 days following application are a combination of loss of seed viability and physical loss of seeds because of extremely heavy rains. The nitrogen rate by tillage interaction was not significant indicating that the effects of nitrogen on shattercane emergence could not be changed by a tillage practice. These results indicate that nitrogen solution applied at normal rates would not be effective in reducing shattercane stands.

Shattercane seed germination was significantly reduced by application of nitrogen solutions at all three temperatures and at each time sampled after

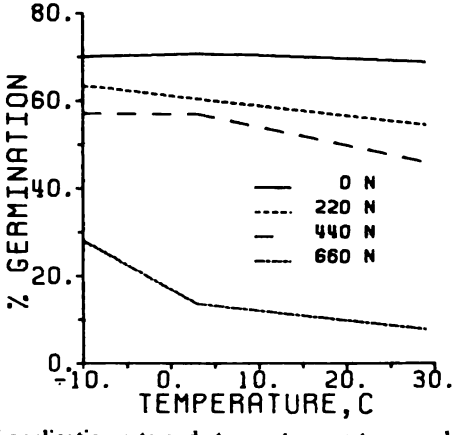


Fig. 1. Effects of N application rate and storage temperature on shattercane germination.

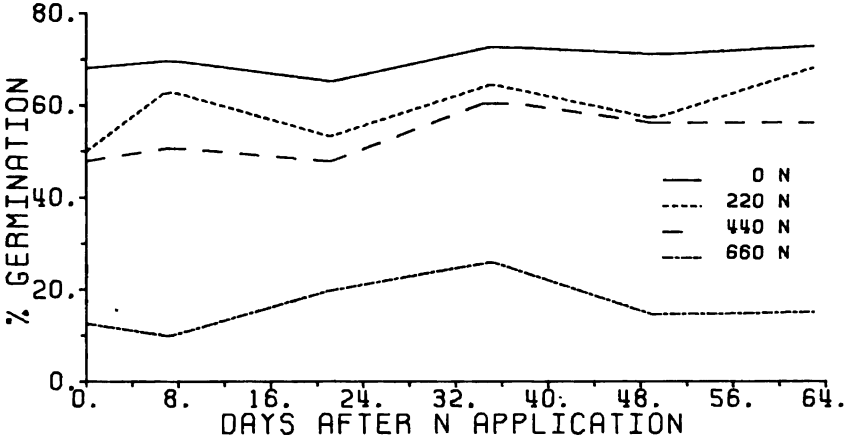


Fig. 2. Effects of N application rate and time after application on shattercane germination.

application. Effects of these factors were not independent as indicated by highly significant interactions between nitrogen rate and temperature, nitrogen rate and time after application, and temperature and time after application. Figure 1 shows that as the nitrogen rate was increased the effect of storage temperature on percent germination also increased. With no nitrogen applied there was essentially no difference in germination over the range from −10 to 29°C. At the 660 kg N/ha rate germination decreased almost

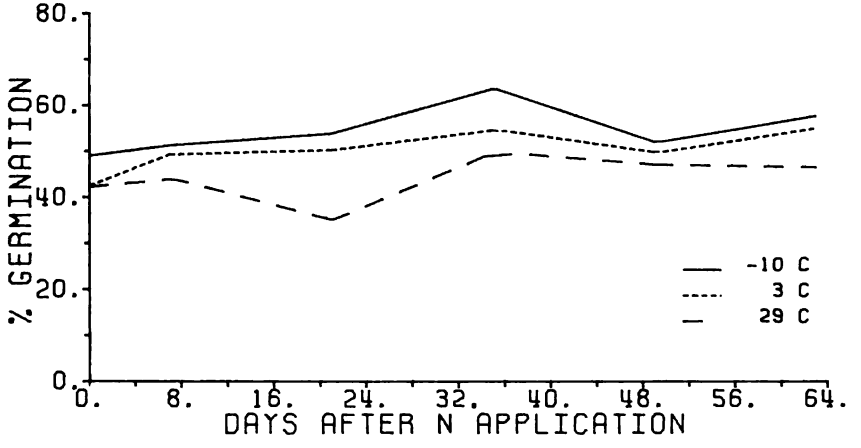


Fig. 3. Effects of storage temperature and time after N application on shattercane germination.

linearly with increased temperature. The other two interactions are less obvious. Figure 2 shows the combined effects of rate of nitrogen application and time after application. Major cause for significant interaction here appears to be the relatively consistent germination percentages for the untreated seed as compared to the fluctuation in germination with time of the nitrogen treated seed. The interaction between storage temperature and time after application (Fig. 3) is primarily due to the relatively low germination percentage 21 days after treatment at the 29°C temperature. We have no explanation for this effect. These results indicate that the effect of high nitrogen application levels produce immediate reductions in germinability of the seed with relatively minor effects of time after application and temperature at which the seed is held. In both experiments the rate of nitrogen application necessary to be of practical significance in controlling shattercane is well above normal application rates (220 kg N/ha or less) and does not provide sufficient reduction in germination to be considered useful for that purpose only.

## Literature Cited

Burnside, O. C. 1965. Seed and phenology studies with shattercane. Nebr. Agr. Exp. Sta. Res. Bul. 230.

Burnside, O. C. 1973. Shattercane: a serious weed throughout the Central United States. Weeds Today 4(2):21.

Jacques, G. L., J. F. Vesecky, K. C. Feltner, and R. L. Vanderlip. 1974. Effects of depth and duration of burial on shattercane seed. Crop Sci. 14:787–789.

Nilson, E. B. 1970. Wild cane and its control. Kans. Ext. Serv. Leaf. 270.

Sexsmith, J. J., and U. J. Pittman. 1963. Effect of nitrogen fertilizers on germination and stand of wild oats. Weeds 11:99–101.

Taylorson, R. B., and C. G. McWhorter. 1968. Seed dormancy and germination in ecotypes of johnsongrass. Weed Sci. 17:359–361.

Thompson, C. A. 1974. Fertilizing dryland grain sorghum on upland soils in the 20–26 inch rainfall area in Kansas. Kans. Agr. Exp. Sta. Bul. 579.

Toole, E. H., S. B. Hendricks, H. A. Borthwick, and V. K. Toole. 1956. Physiology of seed germination. Ann. Rev. of Plant Physiol. 7:299–324.

Vesecky, J. F., K. C. Feltner, and R. L. Vanderlip. 1973. Wild cane and forage sorghum competition in grain sorghum. Weed Sci. 21:28–32.

Watkins, F. D. 1966. Effect of nitrogen fertilizer on the emergence of wild oat (*Avena ludoviciana*). Queensland J. of Agric. and Anim. Sci. 23:87–89.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
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# Production of Pigment Precursors in *Serratia marcescens* at Elevated Temperatures

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ABSTRACT

Using a syntrophic pigmentation assay, strains of *Serratia* were supplied with the uncolored bipyrrole component of the red pigment, prodigiosin. When these assays were performed at 40 C, where red strains are white, it was found that 7 of 10 normally red strains and five of eight clinical white strains formed pigment. This indicates that temperatures which prevent pigmentation in *Serratia* somehow interfere with synthesis of the bipyrrole component of red pigment in a majority of the strains. Also, bipyrrole has an antibiotic range of activity similar to whole pigment.

Until 1970, it was believed that the majority of *Serratia marcescens* strains were pigmented, but work by Grimont et al. (1977), Tabaqchali et al. (1977) and Wilfert et al. (1970), among others, has now shown that up to 70% or more of the isolated strains are nonpigmented. Work on pigment mutants by Rizki (1954) and Santer and Vogel (1956) and others showed that the normal red pigment, prodigiosin, could be formed in white mutants derived from a red strain by the feeding of precursors from a white donor strain to a white acceptor strain. This process is called syntrophic pigmentation, and two of the best characterized syntrophic pigmenting mutants are WF and 933. These strains each produce one of the two colorless precursors of the red pigment. Mutant strain WF produces and donates MAP (2-methyl-3-amylpyrrole), a volatile monopyrrole precursor (Deol et al., 1972) and strain 933 produces and donates the diffusible bipyrrole precursor (Wasserman et al., 1966) MBC (4-methoxy-2,2′-bipyrrole-5-carboxyaldehyde). When grown together, these two strains are able to syntrophically form prodigiosin (2-methyl-3-amyl-6-methoxy-5-(2-pyrryl)-2,2′-dipyrrylmethene) (Hearn et al., 1970).

Syntrophic pigment formation measures the ability of one strain to utilize

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the donated material and couple it with an inherently produced precursor. We used this approach earlier to determine whether or not clinical white (nonmutant) *S. marcescens* strains make one or the other of the two precursors. It was found (Katz and Sobieski, 1979) that 99% of 113 clinical isolates of *S. marcescens* were able to produce syntrophic pigment when fed MBC derived from 933, and that no strains showed any coloring ability when fed MAP. Thus almost all clinical strains of *S. marcescens* presumably synthesize MAP but not MBC.

The temperature experiments reported here used some of the same pigmenting and white strains described previously (Katz and Sobieski, 1979). Nima, OF, and nine clinical strains, along with a *S. rubidaea* strain (although Bergey's Manual of Determinative Bacteriology 8th ed., has determined that all *Serratia* strains are *S. marcescens*, work by Grimont et al. (1977) has shown that there are probably at least four species in the genus *Serratia*) were the red strains used. White strains used were WF, ATCC 8100 (a white *S. marcescens* strain) and seven non-pigment forming strains of clinical origin. Strain 933 was also used in these experiments as the MBC control. The objectives of our evaluations were to determine if any differences exist in the type of precursor produced at different temperatures and the effect of supplying precursors at elevated temperatures to evaluate their coupling by these organisms.

The assays for these experiments used an extraction of 933's MBC with $CHCl_3$ and evaporation of the $CHCl_3$ onto filter paper strips, as described in Katz and Sobieski (1979). These strips when placed perpendicular to a band streak inoculated section of agar, permitted the bacteria to grow in contact with MBC. This allowed the formation of color on the strip of paper.

Before testing the MBC strips for their ability to react syntrophically the red strains were evaluated to determine a temperature at which they remained unpigmented. Temperature intervals were 5 C increments. The maximum tested temperature of red pigment formation was found to be 35 C for all of the red strains (see Table 1). These strains plus several other red *Serratia* strains (a total of 10 red *Serratia* strains) were then incubated at 40 C with MBC strips. Identical cultures, minus the strips, were run as controls and none showed any non-syntrophic pigmentation. Results in Table 1 show that seven of ten of these pigmented *Serratia* strains were able to form syntrophic pigment when incubated at 40 C. Strains unable to form pigment syntrophically were one clinical isolate of *Serratia marcescens*, OF and the clinical isolate *S. rubidaea*. The formation of pigment in the other seven strains demonstrated that their synthesis of MBC had been inhibited by temperature, but that MAP (the volatile monopyrrole precursor) and the coupling enzyme (Williams et al., 1965) must still be active and formed at 40 C, since supplying exogenous MBC allowed pigmentation.

Using the various white strains described above, we found that 5 of 9

Table 1. Temperature limits to pigmentation and syntrophic pigmentation in strains of *Serratia marcescens*.

| Strain color and source | Number of strains | Syntrophic pigmentation ability at 40 C |
|---|---|---|
| Red (Nima) | 1 | + |
| Red (Clinical) | 6 | + |
| Red (Clinical *S. rubidaea*) | 1 | − |
| Red (Clinical) | 1 | − |
| Orange (OF) | 1 | − |
| White (WF and ATCC 8100) | 2 | − (35 C)* |
| White (Clinical) | 5 | + |
| White (Clinical) | 1 | − (35 C) |
| White (Clinical) | 1 | − (30 C) |

* Maximum temperature of syntrophic ability of normally white strains.

were able to produce pigment at 40 C when fed MBC (Table 1). WF and ATCC 8100 and one clinical strain ceased pigment formation above 35 C, while one clinical strain formed pigment only up to 30 C. These results indicate that those white strains unable to form pigment at the highest incubation temperature either had an inactivated coupling enzyme or precursor pathways for MAP or both.

Thus, the lack of pigmentation in *Serratia* strains at elevated temperatures appears to be due to the inability to synthesize a functional MBC precursor to the pigment. Earlier work established that 112 of 113 (Katz and Sobieski, 1979) white clinical isolates of *Serratia* from several sources were found to be lacking this same precursor for pigmentation, even at room temperature incubation. This work supports the idea that temperature selectively inhibits the MBC production in red strains and that supplying MBC to cultures at elevated temperatures overcomes the temperature sensitive defect in the majority of strains.

As controls for these strip assays, various gram positive and negative species were used to evaluate MBC for pigment induction in other bacteria. These species included the following gram negatives: one *Arizona* species, one *Citrobacter* species, two *Enterobacter* species, two *Proteus* species, two *Pseudomonas* species, and three *Escherichia coli* strains. The gram positive species used were *Bacillus cereus, B. subtilis, Micrococcus luteus,* and *Staphylococcus aureus*. Interestingly, it was found that while none of these species showed any ability to form pigment when fed MBC, the MBC was inhibitory to the four gram positive species used, in varying degrees. *M. luteus* was completely inhibited, while the two *Bacillus* species and *Staph. aureus* were inhibited from 10 to 14 mm out from the strips at 24

hours, but after three days of incubation, the growth came to within 1 mm from the edge of the strips. These results indicate that the bipyrrole precursor is an antibiotic with much the same range of activity as the whole pigment (Williams and Hearn, 1967).

In conclusion, temperatures above 35 C prevent pigmentation in red *Serratia* strains by interfering with MBC production. Supplying both red and white strains with the precursor allows for pigmentation in many strains at the elevated temperatures. In addition, the MBC shows the antimicrobial characteristics similar to that of the whole pigment.

## Literature Cited

Deol, B. S., J. R. Alden, and J. L. Still. 1972. The isolation and characterization of monopyrroles from *Serratia marcescens*. Biochem. Biophys. Res. Commun. 47:1378–1385.

Grimont, P. A. D., F. Grimont, H. L. C. Dulong de Rosnay, and P. H. A. Sneath. 1977. Taxonomy of the genus *Serratia*. J. Gen. Microbiol. 98:38–66.

Hearn, W. R., M. K. Elson, R. P. Williams, and J. Medina-Castro. 1979. Prodigiosene (5-(2-pyrryl)-2,2′-dipyrrylmethene) and some substituted prodigiosenes. J. Organic Chem. 35:142–146.

Katz, D. S., and R. J. Sobieski. 1979. Detection of pigment precursors in white clinical strains of *Serratia marcescens*. J. Clin. Microbiol. 9:301–303.

Rizki, M. T. M. 1954. Diffusion of chromogenic inductors of *Serratia marcescens*. Proc. Natl. Acad. Sci. U.S.A. 40:1057–1059.

Santer, U. V., and H. J. Vogel. 1956. Prodigiosin synthesis in *Serratia marcescens*: isolation of a pyrrole-containing precursor. Biochem. et Biophys. Acta 19:578–579.

Tabaqchali, S., T. J. Chambers, and H. J. L. Brooks. 1977. *Serratia marcescens* in hospital practice. Lancet 1:306–307.

Wasserman, H. H., J. E. McKeon, L. A. Smith, and P. Forgione. 1966. Studies on prodigiosin and the bipyrrole precursor. Tetrahedron, Suppl. 8, Part II:647–662.

Wilfert, J. H., F. F. Barrett, W. H. Ewing, M. Finland, and E. H. Kass. 1970. *Serratia marcescens*: biochemical, serological and epidemiological characteristics and antibiotic susceptibilities of strains isolated at Boston City Hospital. Appl. Microbiol. 19:345–352.

Williams, R. P., C. L. Gott, and M. Goldschmidt. 1965. Quantitative aspects of inhibition by temperature of the biosynthesis of prodigiosin. (Abstract) Texas Rept. Biol. and Med. 23:146.

Williams, R. P., and W. R. Hearn. 1967. Prodigiosin. Pp. 410–432. *In* D. Gottlieb and P. D. Shaw (eds.). Antibiotics, vol. 2. Springer-Verlag, Berlin.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
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# Occurrence of Bregmatic Bones in Bobcats (*Lynx rufus*) from Nebraska

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## ABSTRACT

Bregmatic bones were found in 16 of 109 (14.7%) bobcat (*Lynx rufus*) skulls collected in Nebraska. There was no apparent correlation between their occurrence and the age or sex of the specimens.

Bregmatic bones are anomalous bones, varying in size, shape, and number, located at the junction of the sagittal and coronal sutures. In a few mammals they are quite common (e.g. *Castor, Erethizon*) while in others their occurrence is rare (e.g. Canidae) or unreported (e.g. Mustelidae) (Schultz, 1923). Schultz found bregmatic bones in 63 species of mammals belonging to 10 orders. Of the 62 felid specimens he examined, none possessed these bones, but he reported their occurrence in one of 49 felid skulls examined by von Jhering. Hall and Kelson (1959) depicted a bregmatic bone in their illustration of a bobcat (*Lynx rufus*) skull but not in the figure of a lynx (*Lynx canadensis*) skull. Manville (1959) reported only one lynx specimen with bregmatic bones but found these bones in bobcat skulls from Oregon, West Virginia, Mississippi, Texas, and Nevada. My study was conducted to determine the occurrence of bregmatic bones in bobcat skulls from Nebraska.

## MATERIALS AND METHODS

Specimens were obtained from furbuyers, taxidermists, sportsmen, and Nebraska Game and Parks Commission personnel throughout the state of Nebraska during the 1977–1978 and 1978–1979 fur seasons. Skulls were cleaned by boiling and deposited in the University of Nebraska State Museum Zoology Collections after examination.

## RESULTS AND DISCUSSION

Of the 109 skulls examined, 16 (14.7%) possessed bregmatic bones. These results compare favorably with those of Manville (1959). Although Manville noted some geographic variation in frequency, he concluded that these

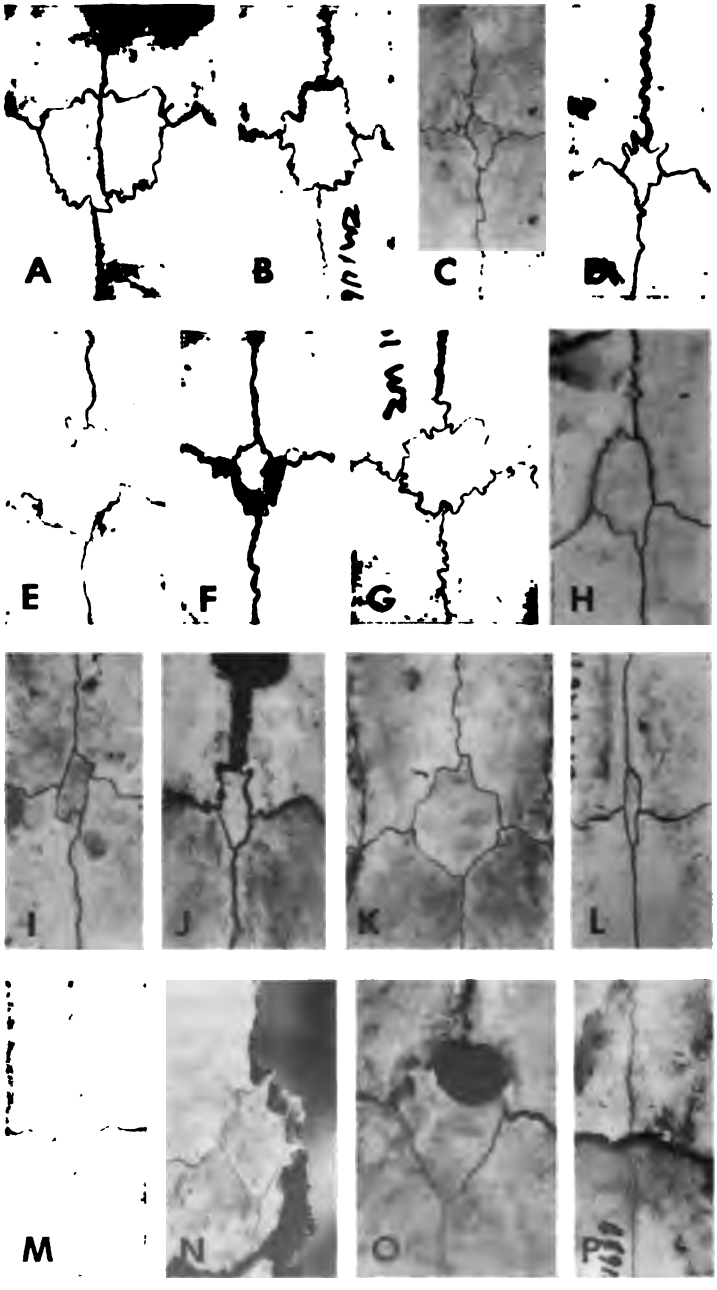


Fig. 1. Variation of bregmatic bones in *Lynx rufus* skulls from Nebraska.

bones occurred in bobcat skulls without regard to geographic origin of the specimen.

Bregmatic bones were present in six of 56 (10.7%) male and 10 of 53 (18.9%) female specimens. One of the 13 adult (over 2 years) males, none of the 13 adult females, four of 27 yearling (1–2 years) males, five of 20 yearling females, one of 16 kitten (0–1 years) males, and five of 20 kitten females exhibited bregmatic bones. I found no apparent correlation between the presence of these bones and the sex or age of the specimens. Similarly, Schultz (1923) and Manville (1959) reported no such correlations.

The variety of sizes and shapes of bregmatic bones is illustrated in Fig. 1. The skull of one female kitten (Fig. 1, A) was the only specimen with multiple bregmatic bones. Schultz (1923) reported the single condition was the most common for most mammals.

The cause of bregmatic bones is not precisely known and their significance has been conjectured by several researchers (see Schultz, 1923 for a review). The variability among species illustrates the need for documentation of the occurrence of these bones in other mammals in order to more fully understand their significance.

## Acknowledgments

I wish to thank the furbuyers, taxidermists, sportsmen, and Nebraska Game and Parks Commission personnel who provided specimens, and Brian R. Mahan who reviewed the manuscript.

## Literature Cited

Hall, E. R., and K. R. Kelson. 1959. The mammals of North America. Ronald Co., New York. Volume 2, pp. 967, 969.

Manville, R. H. 1959. Bregmatic bones in North American *Lynx*. Science 130:1254.

Schultz, A. H. 1923. Bregmatic fontanelle bones in mammals. J. Mamm. 4:65–77.

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# One-Egg Twins in a Snake, *Elaphe guttata guttata*

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There have been few observations reported in the scientific literature regarding normally-formed one-egg twins in reptiles. Reese (1906) cited a case in the American alligator (*Alligator mississippiensis*); Hildebrand (1938), Crooks and Smith (1958), and Yntema (1970, 1971) described the phenomenon for turtles; Singh and Thapliyal (1973) noted two instances in the snake *Natrix piscator*; and Carpenter and Yoshida (1967) reported a case in the lizard *Agama agama*. This report documents another instance of one-egg twinning in reptiles by describing an observation in the corn snake, *Elaphe guttata guttata* Linnaeus.

A second-generation captive-born female (snout–vent length = 102.5 cm; weight = 312.0 g) deposited 17 eggs on 1 June 1979 in a container of moist sand placed in her cage. The eggs were removed on the same day and partially buried in covered trays containing moist vermiculite. The trays were then placed in a dark room maintained at constant temperature (23–24 C). The gross appearance of all eggs was quite similar throughout the incubation period.

Hatching of the clutch commenced on the morning of 26 August 1979, 87 days after oviposition. At 1900 hrs CDT heads or partially-emerged young were noted protruding from all but one egg. On the following morning (27 August) at 0700 hrs, two heads were observed protruding from a single egg. By 1200 hrs, when most other young had already emerged, the larger of the suspected twins had freed itself from the egg but remained attached by its umbilical cord. Subsequent examination of the egg and the other emerging individual revealed that both hatchlings were attached to the same yolk sac by separate umbilical cords which merged proximal to the yolk sac to form a common umbilicus. The separate segments each measured 1.2 cm in length and the common umbilicus extended an additional 0.8 cm to its junction with the single yolk sac. Emergence of both young was completed by 1300 hrs, and sloughing of the umbilical cords accomplished by 2000 hrs.

Fifteen other eggs successfully hatched. Measurements on all hatchlings were taken at the time of their first shed, 10 days after hatching. The larger of the twins measured 24.5 cm snout–vent length (SVL) and weighed 4.10 g, while the smaller was 22.2 cm SVL and 3.05 g. The 15 siblings

had a mean SVL of 28.8 ± 0.4 (SE) cm and a mean weight of 6.38 ± 0.18 g. The smallest of these weighed 4.50 g and measured 24.6 cm, slightly larger than the greater of the twins. The combined weight of the twins (7.15 g) was only slightly greater than the largest of the other young (7.00 g).

The observations reported here are similar in several respects to two cases of twinning reported for another snake, *Natrix piscator* (Singh and Thapliyal, 1973). In the one case where both length and weight were recorded for a set of near-terminal one-egg twins in this species, the total length of each of these twins was also smaller than other individuals at the same stage of development (13.3 and 13.3 cm compared to 14.9 ± 0.4 cm). Likewise, the combined weight of the twins was slightly larger than individual weights of the other embryos (1.492 g compared to 1.367 ± 0.09 g). However, it is interesting to note that in this same occurrence, in contrast to the observation reported here, both twins were approximately equal in size (13.3 cm, 0.750 g; 13.3 cm, 0.742 g). In their other documented case, involving early embryos in only the fourth day of incubation, Singh and Thapliyal (1973) reported a distinct size difference in the twins (0.038 g and 0.029 g). Such inequality in size appears to be the rule rather than the exception for one-egg twins in reptiles, having been observed in most reported cases, and is apparently the result of an unequal development of circulatory connections to the common yolk sac.

Twins may be monozygotic (genotypes identical) or dizygotic (hence, heterogeneic). Monozygotic twins would be formed by an early subdivision of the blastodisc. Dizygotic twins would be most likely formed by two means. Two closely-adjoining fertilized ova could be encapsulated by a single shell in the oviduct. The adjoining yolk masses would then fuse into a common yolk sac as the embryos develop. A second means could be a ctyoplasmic fusion of oocytes in the ovaries. This phenomenon has been described by Dehnel (1929) in a female turtle of the genus *Emys*.

Differences in sex and pigmentation pattern would indicate that the twin *Elaphe* were dizygotic, and hence heterogeneic. As hemipenes are not fully developed in hatchling male snakes, only a tentative classification of sex based on tail length could be made. Males of most species generally have longer tails than those of females (Goin *et al.*, 1978) and, relative to the other siblings, the twins under consideration both appear to be males. No conclusion as to whether these twins are monozygotic or not is indicated on the bases of sex.

The pigmentation patterns, however, are different in both coverage and scale involvement, indicating that the twins are dizygotic. While Singh and Thapliyal (1973) did not comment on pattern or morphological differences in their twin *Natrix piscator*, both Crooks and Smith (1958) and Yntema (1970, 1971) observed in their reported cases of twin turtles (*Terrepene carolina* and *Chelydra serpentina*) that the twins were like-

wise not identical in pattern or morphology. In contrast, Hildebrand (1938) reported that twin *Malaclemys centrata* were identical in pattern and morphology. It thus appears likely that both types of twins can occur in reptiles. Additional observations are needed.

At the time of submission of this manuscript, both of the twin corn snakes have survived and are growing normally, though they remain smaller than their siblings.

## Literature Cited

Carpenter, C. C., and J. K. Yoshida. 1967. One-egg twins in *Agama agama*. Herpetologica 23:57–59.

Crooks, F. D., and P. W. Smith. 1958. An instance of twinning in the box turtle. Herpetologica 14:170–171.

Dehnel, G. 1929. Recherches sur le développement et la génèse des monstres composés chez la tortue Poléise (*Emys orbicularis* L.). Arch. Nauk. Biol. Warsz. Tow. Nauk. 2(2):1–68.

Goin, C. J., O. B. Goin, and G. R. Zug. 1978. Introduction to Herpetology. Third Edition. W. H. Freeman and Company, San Francisco. 378 pp.

Hildebrand, S. F. 1938. Twinning in turtles. J. Hered. 29:242–253.

Reese, A. M. 1906. A double embryo of the Florida alligator. Anat. Anzeigen Jena 28:229–231.

Singh, K. S., and J. P. Thapliyal. 1973. Twinning in the checkered water snake, *Natrix piscator*. Herpetologica 29:19–20.

Yntema, C. L. 1970. Twinning in the common snapping turtle, *Chelydra serpentina*. Anat. Rec. 166:491–498.

Yntema, C. L. 1971. Incidence and survival of twin embryos of the common snapping turtle, *Chelydra serpentina*. Copeia 1971(4):755–758.

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# A New Frog of the Genus *Eleutherodactylus* from Western Panama

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ABSTRACT

*Eleutherodactylus jota* sp. nov. is named from Bocas del Toro province in western Panama. It is closely allied to *E. bransfordii* (with which it is sympatric) and *E. podiciferus* (found at higher altitudes) but readily differs from each in having folds along the forearm and tarsus, a calcar, and a short first toe, as well as in snout shape.

In the course of searching for a Middle American representative of the *discoidalis* Group of *Eleutherodactylus,* I found a small sample of a distinctive *Eleutherodactylus* species from western Panama. Although superficially resembling *E. dolops* Lynch & Duellman, *E. elassodiscus* Lynch, *E. mantipus* (Boulenger), and *E. nigrovittatus* Anderson (the *discoidalis* Group representatives of northwestern South America), the Panamanian frogs have feebly areolate skin of the venter and a short first finger as do *E. bransfordii* (Cope) and *E. podiciferus* (Cope). All of these frogs have broad vomerine odontophores (Fig. 1C).

In the account below, the following abbreviations are employed: SVL—snout–vent length; HW—head width; IOD—interorbital distance; E–N—eye to nostril distance.

## *Eleutherodactylus jota* sp. nov.

*Holotype.* KU 115212, an adult female, obtained along the Río Changena, Provincia Bocas del Toro, Panamá, 830 m, by Linda Trueb 18 May 1966.

*Paratypes.* KU 115213–17, collected syntopically.

*Diagnosis.* A small *Eleutherodactylus* (4 adult females 24.5 to 28.5 mm SVL) similar to *E. bransfordii* (Cope) and *E. podiciferus* (Cope) in habitus but differing from each in having prominent ulnar and outer tarsal folds, a calcar on the heel, depressed snout, and in lacking discs on fingers. The inner metatarsal tubercle is much shorter than the first toe in *E. bransfordii* and *E. podiciferus* whereas it is as long as the first toe in *E. jota.*

*Description.* Head narrower than body, broader than long; HW 40.8–44.2 ($\bar{x}$ = 42.6, $n$ = 6) percent SVL, broadest in two juvenile females; snout ovoid in dorsal view, depressed and somewhat pointed in profile (Fig. 1): snout long, E–N 83.3–100.00 ($\bar{x}$ = 94.4, $n$ = 6) percent eye length; nostrils protuberant, directed dorsolaterally; canthus rostralis sharp, slightly concave; loreal region flat, sloping abruptly to lips; lips not flared; upper eyelid bearing 3–6 small, non-pungent tubercles, its width 44.2–60.5 ($\bar{x}$ = 54.8, $n$ = 6) percent IOD; no cranial crests; temporal region slightly sloping (not vertical); tympanum superficial, annulus not distinct unless specimen dries: tympanum higher than long, its length 60.0–73.9 ($\bar{x}$ = 64.8, $n$ = 6) percent eye length; tympanum separated from eye by distance equal 1–1½ tympanum lengths; supratympanic fold indistinct above tympanum, prominent posterior to tympanum, not concealing tympanic annulus; subconical postrictal tubercles posteroventral to tympanum; a prominent fold extends from posterolateral corner of upper eyelid posteriorly onto anterior flank where it is deflected ventrally as an interrupted series of large warts.

Choanae well lateral on roof of mouth, separated by distance equal to 8–9 times diameter of a choana, not concealed by palatal shelf of maxillary arch; vomerine odontophores of adult females massive, lying between and posterior to choanae, broad, each bearing a transverse row of 9–14 teeth, separated medially by space less than a choanal diameter; in two juvenile females (KU 115213, 115216) there are 6–9 vomerine teeth per odontophore and the odontophores are separated by a distance equalling the width of an odontophore; tongue slightly longer than wide, its posterior border not notched, posterior ½ not adherent to floor of mouth.

Skin of head smooth except for eyelid tubercles, temporal folds, and pair of low postocular folds which converge (but do not touch) just posterior to scapular region and then diverge, becoming inperceptible at about level of sacrum; posterior to sacrum, especially laterally, are isolated, relatively large, subconical warts; just anterior to vent, skin of dorsum bears numerous minute warts; flanks bearing pungent tubercles, becoming smaller, more closely packed, and flatter toward lower flanks; throat and venter smooth except for encroaching tubercles from lower flanks; discoidal folds absent: anal opening not modified, no enlarged para-anal warts; skin on undersides of limbs smooth except for undersides of thighs below and ventrolateral to vent (coarsely areolate).

Upper surface of forearm bearing longitudinal fold reaching to wrist; ulnar edge of forearm with a more prominent fold, feebly crenelate; palmar tubercle flat, slightly longer than wide, not bifid; thenar tubercle flat, oval; supernumerary palmar tubercles indistinct except for two lying between palmar tubercle and basal subarticular tubercle of finger IV; subarticular tubercles not pungent, that on I longer than wide, others round or slightly wider than long; no lateral keels on fingers; finger tips pointed, weakly

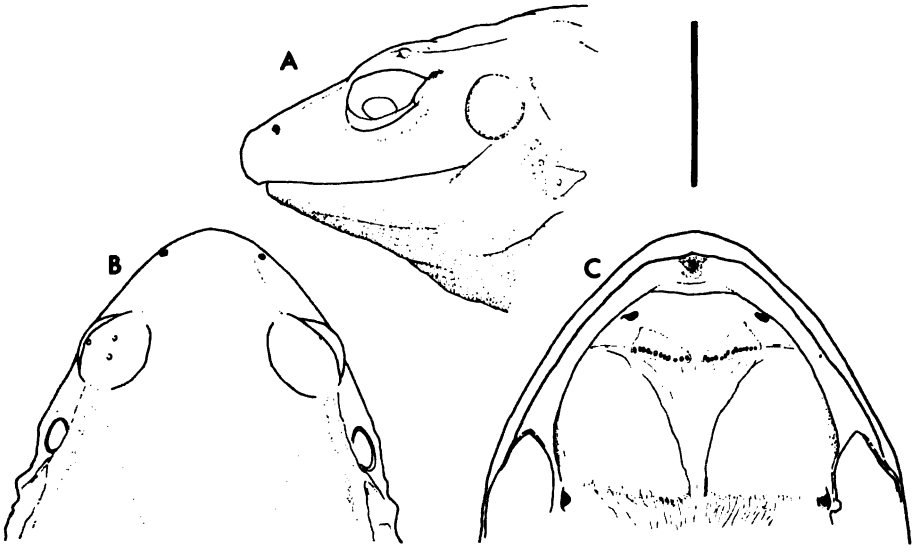


Fig. 1. *Eleutherodactylus jota*. (A) KU 115217; (B) KU 115213; (C) KU 115215. Line equals 5 mm.

bulbous, lacking circumferential grooves (of disc); when I and II are equally adpressed, II slightly longer than I (Fig. 2A).

Distinct subconical tubercles on dorsal surfaces of thighs, tarsi, and feet within limb bars; on shanks, bars enclosed pungent ridges; elsewhere on dorsal surfaces of hind limbs one encounters only minute tubercles; large calcar on heel (Fig. 2B); indefinite cutaneous fold on median edge of shank near heel, extending proximally along distal $^1/_3$–$^2/_5$ of shank; outer edge of tarsus bearing thick, sharp-edged fold (sometimes feebly crenelate); fold extends onto outer edge of sole but becomes indistinct; inner edge of tarsus bearing fold along distal $^1/_2$; no tubercles on underside of tarsus; inner metatarsal tubercle not compressed, as long as toe I, $2^1/_2$ times as long as wide; outer metatarsal tubercle not pungent, $^1/_3$–$^1/_2$ size of inner; plantar surface lacking supernumerary tubercles except in KU 115214 (low tubercles over entire plantar surface); subarticular tubercles longer than wide (basal tubercles toes I–IV) to round (others), more pungent than those of fingers, those on toe V minute; toes lack lateral keels; toe tips pointed, bearing discs (defined by circumferential grooves) on ventral surfaces; toes II–IV bearing expanded pads (about twice width of digit below pad; pad width nearly as wide as length of inner metatarsal tubercle); pads of toes I and V scarcely wider than digit below pad; shank 48.9–52.2 ($\bar{x}$ = 50.6, $n$ = 6) percent SVL.

*Coloration*. Brown above (except KU 115217, gray) with slightly darker

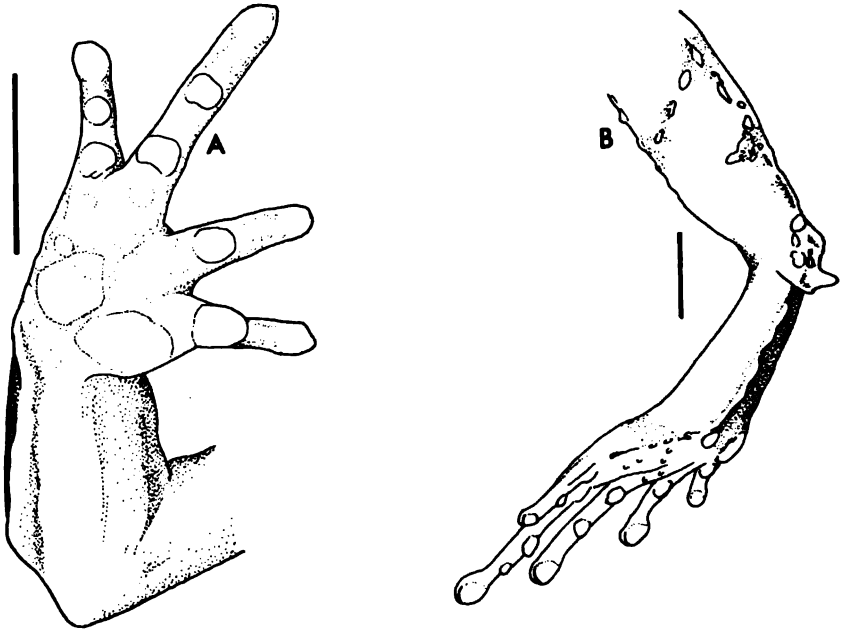


Fig. 2. *Eleutherodactylus jota*. (A) hand and forearm, KU 115215; (B) foot and lower shank, KU 115212. Lines equal 3 mm.

interorbital bar, a pair of dark brown to black spots with pale centers in scapular region (at points of inflection of dorsal ridges), a pair of brown spots on upper flanks (about level of sacrum), and a pair of dark brown suprainguinal spots. Canthus marked by black line (irregular ventral border); black line below temporal fold and covering supratympanic fold; no labial bars; rows of cream spots along upper and lower lips; side of head and flanks immediately posterior to arm darker than dorsum or posterior flanks; warts in this region cream; limb bars dark brown, one on forearm, two on each thigh, shank, and tarsus; limb bars edged with cream; anal triangle black, edged above with cream; groin, anterior and posterior surfaces of thighs, and ventral surfaces of thighs and shanks reddish-brown with minute cream flecks; undersides of tarsi, feet, and forearms black to dark brown with cream tubercles; palm brown with cream tubercles; throat and venter brown with cream flecks and spots; cream spotting most intense in center of chest; throat slightly paler than venter in all specimens except KU 115212 (equally dark).

*Color in life*. Dorsum brown to grayish-brown with pinkish-tan diagonal marks on flanks; posterior surfaces of thighs and ventral surfaces of hind

limbs black; in most, throat orange (or orange-tan) and venter brown or black with bluish-white flecks. In the holotype, throat and venter gray-orange with bluish-white flecks. Iris bronze with red horizontal streak.

*Measurements of holotype in mm.* SVL 27.2; shank 13.3; head length 9.4; HW 11.1; upper eyelid width 1.9; IOD 4.3; tympanum length 1.8; eye length 2.7; E–N 2.6.

*Etymology.* Named for Dr. Jay M. Savage. The specific name is the Spanish letter J, a sobriquet often given that biogeographer.

*Natural history.* All six known specimens are females. The two small individuals (KU 115213, 115216) are juveniles. The six specimens were obtained on the forest floor by day between May 18 and 22, 1966. The frogs were obtained at locality 5 (Trueb, 1968:286).

*Comparisons.* Although placed in different genera by Taylor (1952), *E. bransfordii* and *E. podiciferus* are very similar and presumably closely related (Savage and Emerson, 1970). The former is a lowland frog whereas the latter is a larger upland species. Both have a longer first toe than *E. jota* and neither has ulnar or tarsal ornamentation nor depressed snouts.

*Eleutherodactylus bransfordii, E. jota,* and *E. podiciferus* resemble the *discoidalis* Group species from northwestern South America in habitus, in having broad vomerine odontophores, and in lacking large digital pads and discs. They differ in having a shortened thumb (shorter than the second finger) in contrast to *discoidalis* Group frogs (much longer than second finger) and in having feebly (*jota* and *podiciferus*) to coarsely (*bransfordii*) areolate venters in contrast to the uniformly smooth venters of frogs of the *discoidalis* Group.

## Acknowledgment

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## Literature Cited

Savage, J. M., and S. B. Emerson. 1970. Central American frogs allied to *Eleutherodactylus bransfordii* (Cope): a problem of polymorphism. Copeia 1970(4):623–644.

Taylor, E. H. 1952. A review of the frogs and toads of Costa Rica. Univ. Kansas Sci. Bull. 35(5):577–942.

Trueb, L. 1968. Variation in the tree frog *Hyla lancasteri*. Copeia 1968(2):285–299.

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# Remarks Concerning Certain Western Garter Snakes of the *Thamnophis elegans* Complex

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ABSTRACT

*Thamnophis elegans biscutatus* is a valid subspecies of the Klamath Lakes basin distinguishable from its nearest relatives by size, number of scale rows, head shape, and especially by habits and habitat. *Thamnophis errans* of the Sierra Madre Occidental in Mexico is a distinct species, though closely related to *T. elegans vagrans*, and perhaps to *T. e. hueyi* of Baja California.

In attempting to prepare species-accounts of garter snakes for the Catalogue of American Amphibians and Reptiles sponsored by the Society for the Study of Amphibians and Reptiles, I have been puzzled and intrigued by several taxonomic problems that require clarification. My own original field studies and museum studies of *Thamnophis* were carried on mainly in the period 1933–1936. Obviously, in the period of almost half a century that has elapsed, garter snake classification has made notable progress, with new material, new methods and techniques and more intensive studies, all providing greater insight into the relationships within this complex group. However, some of the facts that were revealed from 15 to more than 40 years ago and that still have important bearing on classification, seem to have been overlooked or forgotten. Hence, I offer the present contribution without having much new data concerning the snakes themselves.

The present report is concerned with two separate problems. The first concerns the validity of the subspecies *Thamnophis elegans biscutatus* endemic to the Klamath Lakes basin, and its relationships to the neighboring allopatric subspecies *T. e. elegans*, *T. e. vagrans*, and *T. couchi hydrophilus*. The second involves the status of the Mexican garter snake *Thamnophis errans*—whether it is a distinct species or intergrades with *T. elegans vagrans* of the southwestern United States.

## VALIDITY OF *THAMNOPHIS ELEGANS BISCUTATUS*

*Eutaenia biscutata* was named by Cope (1883) who referred to it as the most distinct species of the garter snake genus. Van Denburgh and Slevin

(1918) defined it as a localized subspecies of *Thamnophis ordinoides* in the Klamath Lakes basin. Fitch (1940) and Fox (1951) indicated that it was geographically interposed between the more terrestrially inclined *vagrans* and *elegans* on the east and south and the more aquatic *hydrophilus* on the west, linking these ecologically different groups. Later, however, Fox and Dessauer (1965), Lawson and Dessauer (1979), relying on electrophoretic tests, and Rossman (1979), relying heavily on tooth counts, with supplementary data on scutellation ahd proportions, indicated that intergradation could not be demonstrated between *biscutatus* and neighboring *hydrophilus* on the west; the two were thus allocated in separate species, with *hydrophilus* and its aquatic relatives dissociated from *Thamnophis elegans* as *Thamnophis couchi*. Finally, Rossman advocated eliminating the name *biscutatus*, as he concluded that it represented merely an intergradient population between *vagrans* of the Great Basin and *elegans* in the Sierra-Cascade and Coast Ranges.

The polytypic *Thamnophis elegans* as now recognized also includes subspecies *terrestris* of the California coast and *hueyi* isolated in the Sierra San Pedro Mártir range of Baja California. The three subspecies, *biscutatus*, *vagrans* and *elegans*, involved in the present problem are much different in extent of their geographic ranges. *T. e. vagrans* occurs from south-central New Mexico, extreme western Oklahoma and South Dakota, west to the Sierra Nevada and Vancouver Island. Its range is estimated to encompass an area of more than 2 million km$^2$, whereas the range of *biscutatus* is estimated to be only about one percent of this size. The range of *elegans* is of intermediate size, having northern and western branches and a disjunct isolated southern population.

Field observations bearing on the *biscutatus* problem were gained during my early life as a resident of southwestern Oregon, where I knew both *elegans* and *biscutatus*, and recognized them as distinct kinds of snakes, long before I had access to herpetological literature. This early experience, combined with my field study in the 1930s and limited field observations in 1976, have led me to protest the synonymizing of *biscutatus*, as I feel strongly that such action is unwarranted. *T. e. elegans* and *T. e. biscutatus* are similar in general appearance, black or slate with a yellow dorsal stripe, pale lateral stripes, and yellowish dorsolateral flecks, and many of the observable differences between them are rather subtle. However, these differences are real and the two are much different ecologically. *T. e. elegans* is largely terrestrial, relatively slender with a bright yellow dorsal stripe on a velvety black background. *T. e. biscutatus* is much more aquatic, with a duller yellow dorsal stripe on a slaty gray background. Pale flecks on the dark dorsolateral area, that are mostly limited to loose skin between the scales, are different in the two. In *elegans* they are yellow, and smaller, whereas in *biscutatus* they are more prominent and are tinted with green

Table 1. Diagnostic characters of *Thamnophis elegans biscutatus*, *T. e. elegans* and *T. e. vagrans* compared.

| | *biscutatus* | *elegans* | *vagrans* |
|---|---|---|---|
| Dorsal stripe | dull yellow, broad | bright yellow, broad | yellowish tan, narrow with black spots encroaching* |
| Dorsolateral area | slaty gray, faint superimposed black spots; greenish or bluish flecks | velvety black, yellow flecks | pale brown (tan) with small black spots; yellowish or tinted flecks* |
| Snout–vent length (ad. ♂ $\bar{x}$ in mm) | 545* | 457 | 452 |
| Scale rows on body | 23* | 21 | 21 |
| Ventral surface | pale, unmarked | pale, unmarked | pale, usually heavily marked with black areas posteriorly* |
| Head shape, scalation and dentition | | | |
| Preoculars | divided by horizontal suture on one or both sides* | undivided | undivided |
| Posterior supralabials | not noticeably swollen* | markedly swollen | somewhat swollen |
| Shape of snout | medium | borad* | medium |
| Ratio of contacts, internaso-rostral vs. naso-rostral | 1.09 | 1.20* | 1.08 |
| Maxillary teeth $\bar{x}$ | 20.9 | 16.1* | 22.3 |
| Palatine teeth $\bar{x}$ | 12.5 | 9.6 | — |
| Pterygoid teeth $\bar{x}$ | 24.1 | 17.9 | — |
| Dentary teeth $\bar{x}$ | 24.9 | 17.3 | — |

* Indicates a character which sets off that subspecies from the other two.

or blue. Shape of head is strikingly different in the two, broad and short in *elegans*, longer and narrower in *biscutatus*, reflecting terrestrial vs. aquatic adaptation. Bulging cheeks and the enlarged posterior supralabial scale in *elegans* result from enlarged salivary glands as an adaptation to ingest dry, rough-surfaced terrestrial prey, whereas the elongate jaw with increased tooth number in *biscutatus* and its aquatic relatives is probably an adaptation to fish-eating.

Table 1 compares and contrasts a dozen morphological characters in *biscutatus*, *elegans* and *vagrans*. Figures on numbers of teeth are from Ross-

man (1979) but with sexes combined. Other characters are from my (Fitch, 1940) revision. It is evident that each of the three has several distinctive characters of its own, and additional characters shared with one or both of the other two.

In discussing the status of *biscutatus* Rossman (1979) focused attention on certain characters but devoted relatively little attention to others. He demonstrated a consistent difference in the number of teeth, *elegans* averaging between 16 and 17 on each maxillary bone, whereas *biscutatus* averaged about 21. Palatine, pterygoid and dentary teeth similarly are more numerous in *biscutatus* (Table 1). There is sexual dimorphism in number of teeth, with males having, on the average, more than females. However, the average sexual difference amounts to less than one tooth per dentigerous bone in every instance. The separate figures for the sexes have been combined for the comparison in Table 1. On the average, *elegans* has 25% fewer teeth than *biscutatus*. *T. e. vagrans* is more like *biscutatus* in this respect, but has even higher counts. In the original description, the occasionally divided preoculars of *biscutatus* were emphasized as one of its diagnostic features, and were the basis for the name (*biscutatus* = two-scaled). I concur with Rossman that this character alone is too inconstant to warrant recognition of a subspecies, and compared with some of the other differences between the three subspecies, it is relatively trivial.

A much more significant character is the number of scale rows; typically there is a maximum body count of 21 in *elegans* and *vagrans* and 23 in *biscutatus*, but Rossman implied that the difference is unreliable.

Actually there is an average difference of one pair of scale rows on the forebody, but with individual variation and sexual difference. The extra scale row on each side in *biscutatus* is intercalated between the homologues of rows 4 and 5 in *elegans*, and may extend for only a short distance (average 9.3% of snout-vent length) so that it could be missed in making a count at random and certainly would be missed in most specimens by counts made at either neck or mid-body. Usually the maximum count can be obtained at a point approximately one-third of the distance from snout to vent as the intercalated row centers there. In *elegans*, the fifth row on each side is similarly shortened from both front and rear ends and is less than half the length of the corresponding row in *biscutatus*.

Another significant character is body size; *biscutatus* is much larger in maximum, average, and minimum adult size than either *elegans* or *vagrans*, as illustrated by the following snout-vent figures for adult males taken from the histogram in my revisionary study (Fitch, 1940).

*biscutatus* 545 ± 3.76 mm
*elegans* 457 ± 6.10 mm
*vagrans* 452 ± 1.23 mm

Rossman was cognizant of the recorded size difference between the two, but he dismissed it as having no taxonomic significance, implying that it might be explainable by differences in "local environmental conditions." Quality and quantity of food undoubtedly influence adult size in local populations of garter snakes; also there are certainly innate size differences between geographic populations. I am convinced that body size has been unduly neglected in studies in systematic herpetology. Until laboratory broods are reared under controlled conditions to demonstrate lack of significant size difference between *elegans* and *biscutatus*, I urge that the striking size difference between natural populations be considered in assessing their relationships. Ruthven (1908) showed that within each major section of the genus *Thamnophis* there is correlation between body size and number of scale rows; *biscutatus* having the maximum number of scale rows for the genus seems to be a genetically large subspecies.

In a suite of diagnostic characters indicated by asterisks in Table 1, *biscutatus* is not intergradient between the subspecies *elegans* and *vagrans*, but is more different from both of them than they are from each other. It is more aquatic than either, and this is reflected in the shape of the head, especially in the smaller size of the salivary gland and associated supralabial scales (Fitch, 1940). Although the range of *biscutatus* on its northeastern quadrant fronts that of *vagrans* in central Oregon, the two are separated by physical barriers of the divides between drainage systems too high and/or too dry for the snakes to be present. Opportunity for direct intergradation between *biscutatus* and *vagrans* hence is extremely limited; directly to the east of *biscutatus* in the area where three states join, on the Oregon border at the northeastern corner of California and northwestern corner of Nevada, is a population best described as *biscutatus-elegans-vagrans* intergrades (*Eutaenia brunnea* of Cope, 1892). However, the intergradation of *biscutatus* is chiefly with *elegans*. It takes place gradually, over a broad front, from the Klamath basin southeastward across northeastern California in Modoc and Lassen counties (Fitch, 1940).

The relationship between *elegans* and *biscutatus* is complex. *T. e. elegans* occurs in California in the Sierra Nevada, Sacramento Valley, and northern inner Coast Ranges. For adults typical habitat is open oak-pine woodland, but the young do not wander far from water. In the arid region of Lassen and Modoc counties, California, near the northeastern corner of the state, *elegans* becomes much more aquatic in habits, usually is found in or beside streams and takes aquatic prey. To the east of Mt. Shasta, in Siskiyou County, high arid terrain separates the range of *biscutatus* on the north from that of *elegans* on the south. In the western part of its range, *elegans* extends north through western Siskiyou County, California, in the Siskiyou Mountains, and the Rogue River Valley of southwestern Oregon. Thus the range of *biscutatus* is enclosed by that of *elegans* on three sides.

On the southeast they intergrade; on the south they are separated by a barrier; on the west they are most divergent ecologically and morphologically, and their ranges approach each other or may even meet and overlap along the Klamath River. In 1976 I found typical *elegans* at several points along Jenny Creek and Mill Creek, tributaries of the Klamath River, and found typical *biscutatus* along the river 28 km farther east. Habitats of both continue into the intervening zone with no obvious barriers. Rossman (1979) obtained tooth counts with means intermediate between those of *elegans* and *biscutatus* at two intermediate Klamath River localities, COPCO, Siskiyou County, California (5 females) and 11 km ENE Beswick (2 males, 12 females). He interpreted these as showing intergradation, but noted (pers. comm.) that color pattern more nearly resembled *elegans*.

## STATUS OF *THAMNOPHIS ORDINOIDES ERRANS* SMITH

This garter snake was named (Smith, 1942) from six specimens from Colonia Garcia, Chihuahua, and Coyotes, Durango. Subsequently, I noted (Fitch, 1948) that *errans* was geographically remote from members of the *ordinoides-elegans* group and could not be expected to intergrade with any of them. I recommended that it be classified as a distinct species but with relationships to be sought in *T. elegans vagrans*, the geographically closest member of the *ordinoides-elegans* complex. Tanner (1959) reported additional specimens. Finally, Webb (1976), in an admirably thorough study of geographic and individual variation in 124 *errans* and 54 *vagrans* at the southern end of that subspecies' range in New Mexico, concluded that the two kinds intergrade and that the former should therefore be known as *Thamnophis elegans errans*.

Essentially, Webb's findings were that *errans* has an extensive and almost linear range in the pine-oak forests of the Sierra Madre Occidental, from northwestern Chihuahua to southwestern Zacatecas, with geographic variation seemingly clinal in increased number of ventrals, scale rows and supralabials, and in black pigment on ventrals to the north. In all these characters *errans* becomes more like *vagrans* at the northern end of its range where it approaches *vagrans*. Therefore, Webb allocated all specimens (68) from the northern half of Chihuahua (near Colonia Garcia, Chuhuichupa, El Norte, Arroyo Mesteño, Sierra del Nido, Santa Clara, San José Babícora and Yepómera) as *errans-vagrans* intergrades.

The abundant data presented by Webb amply demonstrate that *errans* becomes more different from *vagrans* to the south. However, the alleged northern intergrades are well separated from *vagrans*, spatially and morphologically. A gap of approximately 280 km intervenes, with area of low desert uninhabitable to the snakes, between the northernmost *errans* locality in the Sierra Madre and the southernmost *vagrans* locality, almost due north in the Black Range of New Mexico. Southern *errans* invariably has

a scale count of 19 rows across mid-body according to Webb's data, while in the northern "intergrades" 22% (of 57) have 21 rows at mid-body, and in *vagrans* 87% (of 53) have 21 rows at mid-body. Thus, most "intergrade" northern *errans* are separable from most individuals of adjacent southern *vagrans* even by the rather crude measure of counting scale rows across mid-body. A more refined comparison of the presence and extent of the variable scale row(s) might show a constant difference. The tongue is black or slate gray in all *errans* including the "intergrades," whereas in other garter snakes, including *vagrans*, the tongue is red with a black tip.

*T. e. vagrans* is usually found closely associated with running water, but is less aquatic than many other garter snakes. On the other hand, *errans* evidently is much more terrestrial. "Individuals seem not to frequent ponds or streams; they are often found away from the vicinity of water in damp or even dry places under cover of logs and rocks." (Webb, 1976).

Judging from Webb's photo of *T. errans*, it resembles other terrestrial garter snakes in having the head short and blunt. Head shape in garter snakes is reflected in the proportions of various cephalic scutes. For instance, the contact of the internasals with the rostral is narrow in aquatic kinds, broad in those that are terrestrial. In *errans*, the internasals are broad and truncate anteriorly, as is typical of the terrestrial type. According to Webb, the ratio of internasorostral contact to nasorostral contact is 1.5 (with but little difference between the southern series and the northern "intergrades"). In southern *vagrans* the ratio is markedly lower (average 1.12), and lower still in more northern *vagrans* (Nevada, 1.08; north of latitude 42°, 1.03).

In its terrestrial habitat *errans* resembles *T. e. elegans*, and especially, its southern isolated representative, *T. e. hueyi*, of the Sierra San Pedro Mártir Range in Baja California. In Webb's photograph of a live *errans* the resemblance to *hueyi* is remarkable, but the snake differs from *vagrans* in darker ground color partly obscuring the superimposed dark spots, and in the whitish supralabials, contrasting with the dorsolateral ground color. A distance of a little more than 700 km, with uninhabitable low desert and the Gulf of California, intervene between the nearest localities for *errans* and *hueyi*, respectively. Although they are well isolated at the present time, both may represent a type of garter snake more widespread in the Southwest during past periods of cooler and moister climates.

Similarity in habitat, food habits, appearance and lepidosis between adjacent populations of *T. ordinoides* and *T. elegans terrestris* of the California Coast in Del Norte and Humboldt counties, and between neighboring populations of *T. elegans biscutatus* and *T. couchi hydrophilus* along the Klamath River misled various observers, including myself, to conclude erroneously that intergradation was occurring in the areas of contact. Such instances should inspire caution in assuming intergradation, especially

where there are substantial geographical and morphological hiatuses, and ecological differences are demonstrable, as in the present instance. In comparing *errans* with the most closely related members of the *elegans* group, *vagrans* and *hueyi*, consideration of body size, *lengths* of variable scale rows, proportions of various cephalic scutes, and electrophoretic tests would be appropriate.

## Literature Cited

Cope, E. D. 1883. Notes on the geographical distribution of Batrachia and Reptilia in western North America. Proc. Acad. Nat. Sci., Philadelphia 35:10–35.

Cope, E. D. 1892. A critical review of the characters and variations of the snakes of North America. Proc. U.S. Nat. Mus. 14:589–694.

Fitch, H. S. 1940. A biogeographical study of the ordinoides Artenkreis of garter snakes (genus *Thamnophis*). Univ. California Publ. Zool. 44:1–150.

Fitch, H. S. 1948. Further remarks concerning *Thamnophis ordinoides* and its relatives. Copeia 1948:121–126.

Fox, W. 1948. The relationships of the garter snake *Thamnophis ordinoides*. Copeia 1948:113–120.

Fox, W. 1951. Relationships among the garter snakes of the *Thamnophis elegans* rassenkreis. Univ. California Publ. Zool. 50:485–530.

Fox, W., and H. C. Dessauer. 1965. Collection of garter snakes for blood studies. Year Book Amer. Phil. Soc. for 1964:263–266.

Lawson, R., and H. C. Dessauer. 1979. Biochemical genetics and systematics of garter snakes of the *Thamnophis-elegans-couchii-ordinoides* Complex. Occas. Papers Mus. Zool. Louisiana State Univ. 56:1–24.

Rossman, D. A. 1979. Morphological evidence for taxonomic partitioning of the *Thamnophis elegans* Complex (Serpentes, Colubridae). Occas. Papers Mus. Zool. Louisiana State Univ. No. 55, 12 pp.

Ruthven, A. G. 1908. Variations and genetic relationships of the garter snakes. U.S. Nat. Mus. Bull. 61, 201 pp.

Smith, H. M. 1942. The synonymy of the garter snakes (*Thamnophis*) with notes on Mexican and Central American species. Zoologica 27:97–123.

Tanner, W. W. 1959. A new *Thamnophis* from western Chihuahua with notes on four other species. Herpetologica 15:165–172.

Van Denburgh, J., and J. R. Slevin. 1918. The garter snakes of western North America. Proc. California Acad. Sci. 10:612–1028.

Webb, R. G. 1976. A review of the garter snake *Thamnophis elegans* in Mexico. Nat. Hist. Mus. Los Angeles Co. Contrib. Sci. No. 284, 13 pp.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
83(3), 1980, pp. 114–119

# Constitution and Bylaws of the Kansas Academy of Science

## CONSTITUTION

*Article I.* Name

Section 1. The name of this organization is "The Kansas Academy of Science," hereafter referred to as the "Academy."

*Article II.* Purpose

Section 1. To encourage education in the sciences and dissemination of scientific information through the facilities of the Academy.

Section 2. To achieve closer cooperation and understanding between scientists and non-scientists, so that they may work together in the common cause of furthering science.

*Article III.* Bylaws

The Academy shall establish bylaws concerning the organization and procedures to be followed.

*Article IV.* General Prohibitions

Notwithstanding any provision of this Constitution or the Bylaws which might be susceptible to a contrary interpretation:

1. the Academy shall be organized and operated exclusively for scientific purposes;
2. no part of the net earnings of the Academy shall or may under any circumstance inure to the benefit of any private shareholder or individual;
3. no substantial part of the activities of the Academy shall consist of carrying on propaganda, or otherwise attempting to influence legislation;
4. the Academy shall not participate in, or intervene in (including the publishing or distribution of statements), any political campaign on behalf of any candidate for public office;
5. the Academy shall not be organized or operated for profit;
6. the Academy shall not:
   a. lend any part of its income or corpus, without the receipt of adequate security and a reasonable rate of interest;
   b. pay any compensation, in excess of a reasonable allowance for salaries or other compensation for personal services actually rendered;
   c. make any part of its services available on a preferential basis;

d. make any purchase of securities or any other property for more than adequate consideration in money or money's worth from;
e. sell any securities or other property for less than adequate consideration in money or money's worth from;
f. engage in any other transaction which results in a substantial diversion of its income or corpus to;

any officer, member, or substantial contributor to the organization.

The prohibitions contained in this subsection 6 do not mean to imply that the organization may make such loans, payments or sales to or purchases from anyone else, unless such authority be given or implied by other provisions of this Constitution or Bylaws.

*Article V.* Distribution on Dissolution

Upon dissolution of the Academy, the Executive Council shall distribute the assets and accrued income to one or more organizations as determined by the Council, which organization or organizations shall meet the limitations prescribed in subsections 1 to 6 inclusive, of Article IV immediately preceding.

*Article VI.*

This constitution may be amended by two-thirds of the membership by mail vote.

## Bylaws

*Article I.* Members

Section 1. Membership shall be open to all persons who shall make formal application to the Secretary and pay the prescribed dues.

Section 2. The Executive Council shall have the right to refuse any new member or to terminate the membership of an existing member for cause and without prior notice. However, a terminated person may appeal to the general meeting of the Academy.

*Article II.* The Officers

Section 1. The officers of the Academy shall be of two kinds, elective and appointive.

a. The elected officers shall be President, President-elect, Vice-President, Immediate Past President, Secretary, Treasurer, and six Council Members at Large.
b. The appointed officers shall include an Editor of the official publication, and an Editor of the Academy Newsletter.

Section 2. No one individual may hold two or more elective offices concurrently.

Section 3. The terms of office for the President, President-elect, Vice-President, Immediate Past President, Secretary, and Treasurer shall be one year; those for the Council Members at Large shall be for three years (with election to provide for staggered terms so that no more than two council members shall be elected in any one year).

Section 4. The duties of the elective officers shall be as follows:

a. The President shall preside at meetings of the Academy and its Executive Council; shall be the nominal head of the Academy; shall rule on questions of procedure that may arise; and shall appoint standing and ad hoc committees as needed.
b. The President-elect shall fulfill the duties of the President when the latter is absent; shall succeed the President at the termination of the latter's term; and shall assume the Presidency should that office become vacant during a term.
c. The Secretary shall maintain the records of the Academy and its Executive Council; shall notify the membership of the Academy of pertinent business; shall be responsible for all general correspondence of the Academy; shall maintain the membership roster; and shall be the liaison with the coordinator of the annual meeting.
d. The Treasurer shall keep financial records and accounts of the Academy including all monies received and disbursed; shall receive the annual dues; and shall be responsible for all financial reports required by the business of the Academy. The Treasurer shall be responsible for an annual audit of Academy monies, and shall be responsible for posting a security bond.
e. The Council Members at Large shall serve as members of the Executive Council.
f. The Immediate Past President and Vice-President shall serve as members of the Executive Council.

Section 5. All records and implements of office shall be turned over by any officer to his successor immediately subsequent to the latter's assumption of the office.

Section 6. The duties of the appointive officers shall be as follows:

a. The Editor of the *Transactions of the Kansas Academy of Science* shall be responsible for all phases of publication and may appoint staff members to assist. In general, the Editor will be obligated to implement the stated objectives of the Academy insofar as the publication of a learned journal contributes to those objectives. The Editor is responsible for reporting annually to the Executive Council.
b. The Editor of the Academy Newsletter shall be responsible for all phases of its publication. Inasmuch as the newsletter is the principal mechanism for written communication to the membership, the Editor is obligated to publish all communications of the Academy and its Executive Council on first priority and to include, as space permits,

other items consonant with the stated objectives of the Academy. The Editor is responsible for reporting annually to the Executive Council.

*Article III.* Executive Council

Section 1. The Executive Council shall consist of the President, President-Elect, Vice-President, Secretary, Treasurer, six Council Members at Large and the Immediate Past President.

Section 2. The Executive Council shall be empowered to manage the affairs of the Academy and to designate all appointive officers for terms of one year.

Section 3. The Executive Council shall fill any vacancy occurring among the officers, except that of President, by an appointment for the unexpired term.

Section 4. The Executive Council shall be specifically responsible for the publications of the Academy and shall set such policy as is needed to coordinate the contents of the various media so as to further the stated objectives of the Academy and to insure the availability and distribution of the publications.

*Article IV.* Elections of Officers and Council Members at Large

Section 1. The President shall appoint three members of the Academy to serve as a nominating committee, except that not more than one member of the Executive Council may be appointed to the committee in any one year.

Section 2. The Nominating Committee shall present a slate of at least two candidates for each office to be filled, except that at its discretion, the committee may offer only one candidate for the position of Secretary and one for the position of Treasurer. The slate must be presented at the annual meeting, at which time nominations may be made by the membership.

Section 3. The Nominating Committee, or a member of the Academy proposing a nominee, shall obtain the written consent of the candidate to serve if elected.

Section 4. The President shall appoint an Elector from among the membership who will count the vote.

Section 5. Officers shall be elected by plurality mail vote of the membership.

Section 6. Newly elected persons will take office on the first of January of the year following the election.

*Article V.* Meetings

Section 1. The Academy shall hold an annual meeting at a time and place set by the Executive Council, except when this is contrary to the national interest. Not more than 18 months shall elapse between meetings.

Section 2. The membership shall be informed in writing of the time and place of the meeting not later than one month prior to the meeting.

Section 3. One-tenth of the membership shall constitute a quorum of the Academy at any meeting.

Section 4. Special meetings may be called by vote of a majority of the Executive Council, or on petition of a quorum of the membership. The time and place of such special meetings must be announced to the membership in writing prior to the meeting.

Section 5. All meetings shall be conducted under *Robert's Rules of Order* (Revised).

*Article VI.* Meetings of the Executive Council

Section 1. The Executive Council shall meet at least once a year on the occasion of the annual meeting of the Academy.

Section 2. Any meeting of the Executive Council shall be open to attendance by interested members of the Academy unless the Executive Council moves for Executive Session.

Section 3. A simple majority of the Executive Council shall constitute a quorum.

Section 4. A majority of those present and voting shall be necessary to pass any motion.

Section 5. The meeting shall be conducted according to *Robert's Rules of Order* (Revised).

Section 6. Special meetings of the Executive Council may be called by the President or by a majority of the Council.

*Article VII.* Dues

Section 1. The Executive Council shall be authorized to establish such dues as are compatible with the financial status of the Academy.

Section 2. A member in arrears for payment of dues for a period of 6 months shall be dropped from the membership roll.

*Article VIII.* Fiscal Year

Section 1. The fiscal year of the Academy shall embrace the period from 1 January of any year through 31 December of the same year.

*Article IX.* Amendment of Bylaws

Section 1. Amendments may be proposed by the Executive Council or by petition to the Secretary by ten or more members of the Academy.

Section 2. Proposed amendments must be submitted in writing to the Secretary one month before the meeting at which they are to be discussed.

Section 3. Such amendments shall be submitted in writing by the Secre-

tary to the general membership at least two weeks prior to the meeting at which they are to be discussed.

Section 4. To be approved, an amendment must receive a positive vote by two-thirds of those voting at the meeting.

Section 5. Any adopted amendment shall become an integral part of the Bylaws and the Secretary shall be instructed to add them to copies of the Bylaws and to distribute the amended Bylaws to the members of the Executive Council and to other interested members of the Academy.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
83(3), 1980, pp. 120–160

# Kansas Academy of Science
# Abstracts of Papers Contributed to the Program
# 112th Annual Meeting, Fort Hays State University
# Hays, Kansas, 28 March 1980

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A RADIOISOTOPE METHOD FOR ESTIMATING INGESTION AND FILTERING RATES OF CLAY PARTICLES BY DAPHNIA. J. A. Arruda and G. R. Marzolf, Division of Biology, Kansas State University, Manhattan, Kansas 66506.

Most rivers of the Great Plains and their reservoirs are turbid with suspended inorganic silts and clays. The production and biomass of phytoplankton algae are limited by the reduced light. Zooplankton, on the other hand, do not seem to be reduced in numbers, and they do ingest silts and clays.

In order to interpret the effects of suspended clays in the diet of zooplankton in turbid reservoirs, it is first necessary to measure their filtering and ingestion rates in suspensions of clay particles. A method using the adsorption of the radioisotope Zinc-65 onto clays has been developed.

Adsorption of Zinc-65 is dependent on pH. Maximum adsorption occurs at pH 9.0 and is essentially complete within 30 minutes of radioisotope addition. Adsorption sites are not saturated by concentrations of Zinc up to 450 microCuries/mg clay.

Initial feeding experiments were performed with *Daphnia parvula*, *D. pulex* and *D. similis* cultured from Tuttle Creek Reservoir. Ingestion and filtering rates differ between species and increase with body size within a species.

SOLAR PANEL EFFICIENCY MEASUREMENTS AT PSU. Robert J. Backes, Department of Physics, Pittsburg State University, Pittsburg, Kansas 66762.

The implementation of a solar research program within the Physics Department of Pittsburg State University will be reported on. The apparatus assembled to perform solar panel efficiency measurements, including a data acquisition system incorporating an OSI Challenger Computer, will be described. The results of some initial measurements will be presented as well as a cost analysis of the research program and a rationale statement for the program.

ENERGY AND POLLUTION ABATEMENT—THE BASIS FOR AN ENERGY EMERGENCY MANAGEMENT OPTION. DeWayne Backhus, Department of Physical Sciences (Earth Science), Emporia State University, Emporia, Kansas 66801.

As supplies of conventional sources of energy have become more tenuous and interruptible, state agencies have recognized the need to develop energy emergency contingency plans as part of an overall energy management function.

One situation-specific response available to states based on Section 110(f) of the Clean Air Act is to request a relaxation of air pollution abatement requirements at coal- and/or oil-consuming installations. Such relaxations or variances might be deemed desirable during circumstances of inadequate supplies of fuels necessary to comply with the maintenance of ambient air quality standards, or to enable the energy normally consumed "in-house" for pollution abatement to be re-directed to the distribution network for consumption by other sectors. Coal- or oil-related shortages resulting from a number of possible circumstances could potentially involve utility steam plants, as well as numerous industrial, commercial, and institutional facilities.

The presentation will be based on a sabbatical involvement with the Tennessee Energy Authority on a National Science Foundation-supported SSET (State Science, Engineering, and Technology) project. In such a State heavily dependent on coal, the effects of the 1977-78 coal miner's strike initiated the study. A case example will be presented using the coal-fired steam plants of the Tennessee Valley Authority in Tennessee as the basis for the issue of energy production versus environmental protection during a bona fide energy emergency based on criteria of the Clean Air Act as amended.

LINEAR ACOUSTIC MODEL FOR THE EXHAUST DUCT OF A PULSED CHEMICAL LASER. Roy J. Beckemeyer, Technology Development, Boeing Military Airplane Company, Wichita, Kansas 67210.

The photo-initiated reaction in a typical pulsed chemical laser produces transient disturbances in the medium with peak pressure magnitudes on the order of 10 atmospheres and temperatures of up to 3500°K. The quality of the emitted beam is influenced heavily by the chemical and optical homogeneity of the medium at the time of initiation; it is thus necessary to attenuate the reaction-generated disturbances in the short time between laser pulses. Typical requirements are reduction of disturbance magnitudes to the range of $10^{-3}$ to $10^{-5}$ atmospheres in times of $10^{-2}$ sec. While the initial disturbance is decidedly nonlinear, the acceptable perturbation levels are within the limits of traditional small disturbance theory, and complete analyses of the fluid dynamics of the clearing process must span the entire range of magnitudes. This paper deals with one end of that range and describes a computational model, based on linear acoustic theory, that has been used to gain insight into the effects of conventional acoustic attenuation devices on laser cavity clearing times. The model developed is for one-dimensional

wave propagation in channels with nonuniform geometry, nonuniform wall acoustic-impedance properties, and nonuniform medium properties. The method of inner and outer asympotic expansions has been used to develop a transfer matrix computational model that produces a reaction-cavity reflection coefficient spectrum. Results are shown which illustrate the effects of the axial location of a slug of heated gas on the reflection coefficient spectrum of an acoustically-treated exhaust duct.

PERMIAN REDBED COPPER MINERALIZATION IN SOUTHCENTRAL KANSAS. Pieter Berendsen, Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66044.

Eighty-seven meters (284 feet) of core was recovered from sixteen drill holes penetrating the upper part of the Wellington Formation, the Ninnescah Shale, and the lower part of the Harper Sandstone in order to evaluate the occurrence of copper mineralization in the subsurface and to better understand the environment of deposition. The deposits are zoned and show the following paragenetic sequence of mineralization: pyrite → chalcopyrite → bornite → digenite → anilite → djurleite → covellite → azurite → malachite. The sequence is interpreted as indicating a drop in copper content of the ore fluid as distance from the source of copper increased. Source of the copper may be the ancestral positive elements underlain by igneous rocks which surrounded the Permian basin. Another possible source, which has never been considered, is the Keweenawan basalt associated with the Central North American Rift System. Copper is believed to have been absorbed on clays brought into the Permian sea. Later sealevel lowering and oxidation of the rocks by solutions containing low concentrations of chlorides derived from the sediments remobilized the copper and concentrated it in favorable horizons.

Lithologic and stratigraphic evaluation of the materials indicate that both the Milan Limestone member of the Wellington Formation and the Runnymede Sandstone member of the Ninnescah Shale should be dropped from the official stratigraphic column in use. Neither unit is traceable on the surface for any distance and not at all in the subsurface.

WATER QUALITY CONCERNS OF THE JOHNSON COUNTY (KANSAS) UNIFIED SEWER DISTRICTS. Betsy Betros, Johnson County Unified Sewer Districts, Mission, Kansas 66201; Lynda Swander, Division of Natural and Health-Related Sciences, Johnson County Community College, Overland Park, Kansas 66210.

According to the final Water Quality Management Plan (208) for the Kansas City Metropolitan Region (KCMR), nonpoint pollution sources have not been identified and additional information must be collected in order to identify the sources, determine their impact on water quality and develop

control measures if necessary. The impact of nonpoint pollution on stream quality is assessed by comparing the levels of pollutants in the stream during and after runoff with water quality standards for those pollutants. In addition to water measurements, sediment analysis for metals content is necessary as well as measuring the macroinvertebrate communities of the stream to determine the effects of the water quality on the biota.

As an out-growth of the 208 findings, the Mid-America Regional Council, Johnson County (Kansas) Unified Sewer Districts, City of Independence (Missouri) and other technical consultants are involved in the Nationwide Urban Runoff Program (NURP). NURP is a set of thirty studies in key cities throughout the nation funded by the U.S. EPA. The Johnson County program involves studying runoff effects on Indian Creek from three land-use areas: light industrial, residential and shopping center.

The macroinvertebrate analysis of the creek is a major part of the Johnson County study. The sewer district has an on-going stream monitoring program on Indian Creek. Preliminary results indicate that urban runoff may have a significant adverse impact on the water quality and biota of Indian Creek. In order for the county to better assess problems with nonpoint source pollution, Johnson County Unified Sewer Districts decided to seek a NURP grant. This paper will describe the NURP grant and the ongoing macroinvertebrate surveys.

THE FIRST TWENTY YEARS: A BRIEF HISTORY OF THE UNIVERSITY OF KANSAS' OBSERVATORY FROM 1919–1939. Donald J. Bord, Department of Physics, Benedictine College, Atchison, Kansas 66002, and Department of Physics & Astronomy, University of Kansas, Lawrence, Kansas 66045.

The history and development of the University of Kansas' Observatory is traced from its construction in 1919 under the direction of Dr. Dinsmore Alter to the dedication of its principal instrument, the William Pitt 27-inch reflector, in February 1939. The discussion will focus on some of the more remarkable aspects of the construction and design of the Observatory and its facilities, as well as on several of the fascinating personalities involved in the various stages of the Observatory's development. Special consideration will be given to Professor Alter, whose continuous efforts over a 19-year span led to the establishment of the Observatory, and to Mr. William Pitt, a prominent Kansas City businessman, in whose emptied basement swimming pool the 27-inch primary mirror of the University's telescope was ground and polished.

MOVEMENT AND LOCOMOTION OF *VANNELLA MIRA*, A MARINE AMEBA, IN THE RADIATE FORM. Eugene C. Bovee and Elizabeth A. Bovee, Department of Physiology and Cell Biology, University of Kansas, Lawrence, Kansas 66045.

Radiate forms of naked, lobose amebas are usually believed to be passive pelagic states. Locomotion is usually assumed to be characteristic of the creeping or crawling form. Schaeffer (1926) saw tumbling and pirouetting of the radiate form of *Vannella mira*. We have confirmed his observations, but also find that the radiate form actively "walks" on its pseudopods. By repeated extension and contraction of some of its radiate pseudopods, the ameba changes its center of gravity and progresses forward (or backward) in a rolling "walk." The radiate form also pulls itself along over and through debris by extending pseudopods that adhere to debris and contract forcibly to pull the body along at rates faster than the creeping rates. The reported maximal crawling rate is 75 $\mu$m/min for *V. mira*, with mean crawling rate being 25 $\mu$m/min. The maximal "walking" rate of the radiate form is 2–5 $\mu$m/sec (120–300 $\mu$m/min) for short distances and somewhat exceeds the mean crawling rate at a steady rolling advance. (Facilities provided for this research by the Microbiology Department, Oregon State University, Corvallis, Oregon.)

PROGRESS IN MAINTAINING AND ESTABLISHING PRAIRIE IN THE BAKER WETLANDS. Ivan L. Boyd, Baker University, Baldwin, Kansas 66006.

A 573-acre tract of land along the flood plains of the Wakarusa River was acquired by Baker University in the fall of 1968. Immediate steps were taken to preserve this native wetland meadow and to begin the establishing of prairie plantings in selected areas of the tract. Pure stands of Indian grass, big blue stem, switch grass and bush lespedeza have been developed so that large quantities of these seed could be harvested by combine equipment. Seeds of other species of prairie plants have been collected locally by hand. Additional new plantings are made each year with the use of the available harvested seed. The ultimate goal of this project is to bring back the entire area to its natural state including the improvement of the wooded area along the banks of the river.

THE HOME RANGE OF THE EASTERN COTTONTAIL RABBIT (*SYLVILAGUS FLORIDANUS ALACER*) IN STRIP-MINED LAND. John M. Briggs and Horace A. Hays, Department of Biology, Pittsburg State University, Pittsburg, Kansas 66762.

A radio-telemetry study of the home range of the eastern cottontail rabbit was conducted at the Pittsburg State University Natural History Research Reserve. This study was initiated in September 1977 and was terminated in December 1979. Twenty-four different rabbits were captured and 10 were fitted with transmitters. This study indicates that the size of the home range is smaller in strip-mined land than in other areas and that the home range varies with the size, age, and sex of the individual rabbit. The average size of the home range for all the rabbits studied was .32 hectares.

A NEW FERN HYBRID—*WOODSIA OBTUSA* × *OREGANA*. Ralph E. Brooks, Herbarium, University of Kansas, 2045 Avenue A, Campus West, Lawrence, Kansas 66044.

On the basis of morphological studies, including SEM examinations, several plants from Central Kansas are shown to be probable hybrids of *Woodsia obtusa* (Spreng.) Torr. and *Woodsia oregana* D. C. Eat. This cross has not been previously reported. In the Great Plains region the distribution of *W. obtusa* is primarily restricted to the eastern and southern areas while that of *W. oregana* includes more western and northern areas. Recent field and herbarium studies of Central Kansas indicated there was a small zone of overlap between the distribution of the two species in that area and eventually led to the discovery of a hybrid swarm of the two woodsias in McPherson County, Kansas. Both parental species are morphologically typical of the respective species while the hybrids display quite intermediate characteristics.

GEOLOGIC RESEARCH IN KANSAS BEFORE 1864. Rex C. Buchanan, Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66044.

The creation of the first geological survey of Kansas in 1864 marked the institutionalization of science in Kansas government. Yet there was significant geologic research in the state well before 1864, and its history can be broken into two distinct periods: the first was one of initial observation—characterized by the search for economically attractive minerals—and the second included sophisticated geologic reconnaissance and resulted in important contributions to geologic knowledge. That first period began with the early exploration of the state; its most notable component was the search for valuable minerals, especially gold and silver. Later attention turned to more practical deposits, such as coal and stone. Included in that first period was the propagandistic use of geologic information in attempts to woo settlers to the state during the era of "Bleeding Kansas." Concern over applied geology continued into the second period, which began in the 1850s with the work of Swallow, Hawn, Meek, and Hayden and was largely related to the maturation and professionalization of geology as a discipline in America. The second period was highlighted by increased geologic mapping, the first complete cross-section of Kansas, a heated priority dispute over the discovery of the Permian in North America, and the greater concern for geology as a basic science.

GEOCHEMISTRY OF WATERS FROM THE WILDCAT CREEK IN RILEY COUNTY, KANSAS. Bradley T. Burkett, Department of Geology, Kansas State University, Manhattan, Kansas 66506.

To assess the quality of water of the Wildcat Creek, samples for chemical analysis were collected from the main channel and its tributaries within the city of Manhattan area over a period of four months from October 1979 to

February 1980. The pH values for the samples collected in October ranged between 7.5 and 7.9, whereas those collected during the winter indicated values between 3.5 and 7.8. The low pH's were noted for waters from the two extreme downstream sites of the main channel observed for this study. Although the exact cause of the low pH's cannot be determined at this time, they seem to be unrelated to chloride, sulphate or carbonate contents of the waters. The total dissolved solids vary from an average value of 550 ppm during the period of an apparent high discharge in October to an average value of 1070 ppm during the low discharge in February. The high total dissolved solids are related to high sodium and chloride contents of the waters. The two highest values of 1500 ppm and 1350 ppm of total dissolved solids have been recognized for waters with low pH values. Ca, Mg, Fe, Na, K, Sr, Cl, $SO_4$, and $CO_3$ contents are within the average values reported for many waters in carbonate terrains. All waters from the Wildcat Creek and its tributaries appear to be supersaturated with respect to calcite and undersaturated with respect to gypsum and celestite.

*NEOCHONETES GRANULIFER* AND THE FLORENA SHALE. B. T. Burkett, C. W. Chandler, J. A. Green, M. J. Greene, W. B. Kolins, R. G. Lowry, J. S. Mullenax, H. A. Taylor, E. L. Ward, and G. R. Clark II, Department of Geology, Kansas State University, Manhattan, Kansas 66506.

*Neochonetes granulifer,* a chonetid brachiopod, is an extremely abundant fossil in the Lower Permian Florena Shale, so dominating the fossil remains that it would seem to have been very well suited to its environment. On the other hand, the greater part of the *Neochonetes* population consists of extremely small shells, implying that for juveniles, at least, the environment was extremely unfavorable. Eighteen collections of *Neochonetes granulifer* were made from two exposures fo the Florena Shale near Manhattan, Kansas; these were then studied individually and collectively to define the allometry and population dynamics of this fauna. The results suggested that the juvenile and adult members of the population were adapted to different ecologic niches, and that the population had mixed success in both recruitment and the assimilation fo the juveniles into the adult population. Several models, involving various assumptions of growth rate, paleoenvironment, and unpreserved faunal and floral elements, are considered in the interpretation of the life history and ecology of *Neochonetes* in the Florena paleoenvironment.

PROPERTY RIGHTS IN A FUGATIVE RESOURCE: ALTERNATIVE MECHANISMS FOR CONTROL OF WATER RESOURCE DEVELOPMENT IN WESTERN KANSAS. David R. Collins, Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66044.

Governments or quasi-governmental agencies impose institutional controls on the use of scarce resources (e.g., conditional property rights, priority of use, user fees) in a presumed attempt to obtain a "better" use of the resource. The following questions are therefore of prime importance to both the resource user and the controling agency: (1) Within the existing institutional framework, what is the "best" way to utilize a scarce resource? (2) Would the "best" use of the resource be different under an alternative institutional framework? (3) If the optimal use of the resource is sensitive to changes in the institutional framework, then which institution is better? This paper addresses these questions in the context of groundwater resources in western Kansas using a simple optimal control model. The model highlights the construction of delivery capacity and the allocation of water made available by this capacity within the institutional constraints embodied in the model. An optimal program will then be an optimal delivery capacity and an optimal delivery of water. Optimal programs are characterized under alternative institutional constraints and comparisons of optimal programs are made. Brief consideration is also given to characterizing the conditions under which it is optimal to change the institutional framework.

THE ORIGINS OF HOMOIOTHERMY. Eleanor Daly, Department of Systematics and Ecology, University of Kansas, Lawrence, Kansas 66045.

The selection pressures that produced the constant high body temperatures of mammals and birds are still under discussion. A constant body temperature, high or low, maintains an animal's muscular efficiency and coordination at its best. A high constant temperature confers a capacity for sustained activity, because the resting rate of oxygen consumption is related to the maximum possible rate. Despite the competitive advantages that this confers, the energetic cost of a high BMR seems prohibitively great.

Early mammals were small nocturnal animals. We know this because of the peculiarities of their vision, and the high development of their smell and hearing. It is difficult to control body temperature ectothermically after dark, when the environment cools to a level. The ancestors of mammals came under selection for sustained muscular activity, as the means to keep their temperatures at their optimum endothermically. When a high constant temperature developed, the muscular activity ceased to be necessary. Avian homoiothermy is reasonably thought to be connected with flight, which certainly requires a capacity for sustained activity. But birds fly with their feathers, and the feather cover must have appeared together with their homoiothermy. If homoiothermy developed before flight, in birds or their ancestors, its origin is inexplicable. We must suppose that flight arose first, with the proavis gliding on skin membranes. Over time, powered flight, homoiothermy and insulation were selected for. Eventually, lengthening feathers replaced the patagium, due to the numerous advantages of feathers as flight surfaces.

ABSENCE OF GOLD IN CHEMICALLY PECULAR STARS. J. P. Davidson, Department of Physics and Astronomy, University of Kansas, Lawrence, Kansas 66044; Donald J. Bord, Department of Physics, Benedictine College, Atchison, Kansas 66002.

During the last decade earth based observations of early type (B or A) stars have shown the existence of a fairly large group of chemically peculiar (Cp) stars with unusually large ($>10^5$ cosmic or solar) abundances of the heavy metals ranging from W-Tl. A subset of these is the mercury-manganese (Hg-Mm) stars with large Hg abundances which also display overabundances of Pt. However, no evidence of the element Au has been found in this group of stars (currently 20 or 30 have been studied). Proposed theories to explain their unusual abundance such as radiation driven diffusion or selective magnetic accretion do not seem to exclude Au since its atomic properties are similar to its neighbors. In particular, the first ionization potential of Au lies between those of Pt and Hg, while the magnetic susceptability is very close to that of Hg. Au is unusual among its heavy metal neighbors only in that it is monoisotopic. The failure to detect Au in Cp stars may be an artifact of the earth based observations since the majority of the strongest lines of AuI and AuII have wavelengths shorter than 3300 A—which condition obtains for Pt and Hg and indeed all the elements between W and Tl. If ultraviolet observations show Au absent or of only cosmic abundance serious questions concerning the stellar concentration theories or theories of nucleogenesis formation theories will arise. If gold is in fact not present then it is necessary to postulate methods for its removal from the atmospheres of Cp stars. The nuclear physics consequences of such removal will have an important bearing on the development of these stars. These questions as well as methods of Au removal will be discussed.

REVISIONS FOR FOLK'S CLASSIFICATION OF CARBONATE ROCKS. Daniel A. DeBoer, Department of Earth Science, Fort Hays State University, Hays, Kansas 67601.

In order to make the Folk classification of carbonate rocks more useful some additions and revisions concerning pisoliths and oncolites are suggested. Carbonate rocks containing non-vadose pisoliths and algal oncolites will form as a result of depositional processes, therefore, the resulting rocks will be either sparry allochemical (Type I), microcrystalline allochemical (Type II), or microcrystalline (Type III). In considering the volume of pisoliths and oncolites in carbonate rocks new prefixes, "piso-" and "onco-," are introduced. When these prefixes occur in a rock name it means more than 25% of the rock is composed of oncolites or pisoliths. The resulting rock names would be "oncomicrudite," "pisosparrudite," etc.

In the case of vadose pisoliths, which form in place as a result of diagenetic processes, the term "pisolithite" should be used. This revision would

change Folk's "undisturbed bioherm rocks" (Type IV) to "framework limestones" or "undisturbed limestones" to include both the biological (bioherm) and the non-biological (pisolithite) rocks.

Replacement dolomites (Type V) which contain more than 25% pisolith and oncolite ghosts would simply be called "pisolithic dolomite" or "oncolitic dolomite."

THE EFFECTS OF ELEVATED ARTERIAL $P_{CO_2}$ ON TOTAL AND REGIONAL CEREBRAL BLOOD FLOW IN THE NEW ZEALAND WHITE RABBIT. R. C. DeSoignie, J. A. Orr, L. C. Wagerle, D. B. Fraser, M. L. Gouverne, Department of Physiology and Cell Biology, and B. Friesen, Department of Biochemistry, University of Kansas, Lawrence, Kansas 66045.

Numerous studies have demonstrated that increases in the partial pressure of arterial $CO_2$ ($P_{CO_2}$) significantly elevates cerebral blood flow in humans and other animal species. To further elucidate this relationship the response of the cerebral circulation to hyperoxic hypercapnia was measured in 7 anesthetized New Zealand White Rabbits. Total and regional cerebral blood flow was determined via the tracer microsphere method. Radioactive microspheres (15 $\mu$ in diameter) labeled with $^{46}Sc$, $^{113}Sn$, or $^{57}Co$ were injected into the left atrium and a reference arterial blood sample withdrawn from the right femoral artery. Blood flow to the cerebrum, pons, midbrain, cerebellum, and medulla oblongata were determined during control and hypercapnic states. During hypercapnia total and regional blood flows increased as follows: total brain +113%, cerebrum +93%, medulla oblongata +148%, cerebellum +179%, pons +111%, and midbrain +140%. The data suggest that distribution of brain blood flow may be altered during hypercapnic conditions. (Support for this research was provided by a grant from the American Heart Association-Kansas Affiliate, Award #79-KS-530.)

| | Control #1 | Treatment | Control #2 |
|---|---|---|---|
| Arterial $P_{CO_2}$ (torr) | 43.8 | 79.7 | 43.4 |
| | 2.3 | 3.8 | 1.1 |
| Arterial Blood Press. (torr) | 70 | 71 | 68 |
| | 5 | 5 | 5 |
| Brain Blood Flow (ml/min/g) | 0.768 | 1.639 | 0.674 |
| | 0.081 | 0.215 | 0.038 |
| Cerebrum | 0.860 | 1.656 | 0.735 |
| | 0.102 | 0.232 | 0.057 |
| Cerebellum | 0.708 | 1.973 | 0.690 |
| | 0.081 | 0.289 | 0.027 |
| Medulla Oblongata | 0.520 | 1.291 | 0.528 |
| | 0.104 | 0.166 | 0.035 |

Values are means (±SE)

Trecil D. Dreiling, Department of Chemistry, Kansas State University, Manhattan, Kansas 66506.

The flowing afterglow technique has been used to study the dissociative excitation of $HgX_2$ (X = Br, Cl) by metastable Xe ($^3P_2$). Visible emission from HgX ($B^2\Sigma^+ - X^2\Sigma^+$) was used to assign rate constants for production of HgX(B). The measured rate constants at 425°K were determined as 123 $\pm$ 8 $\times$ $10^{-11}$ and 95 $\pm$ 10 $\times$ $10^{-11}$ $cm^3$ $molecule^{-1}$ $sec^{-1}$ for HgCl and HgBr respectively. Similar studies have been performed with $N_2(A^3\Sigma_u^+)$ as the excitation source.

THE CURRENT STATUS OF BSCS BIOLOGY IN KANSAS. Harold E. Durst and John C. Ransom, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

This survey was designed to compare the extent that BSCS biology was being used in Kansas secondary schools in 1977–78 to its utilization in 1967–68. The study includes four areas of concern to teachers and curriculum planners: (1) usage of BSCS materials, (2) teaching facilities and conditions, (3) teacher training and experience, and (4) teacher opinions as to the comparative value and difficulties of BSCS to other biology offerings. A questionnaire designed to obtain data regarding the four areas was sent to 470 public school biology teachers in Kansas in the Spring 1978. Three hundred fifty three (75%) returned the questionnaire.

Forty percent of the respondents were teaching some type of BSCS biology in 1977–78 compared to 34% in 1967–68. The total number of students enrolled in courses using BSCS materials increased by 5714 to a total of 18,344 in 1977–78. The use of *Molecules to Man* remained steady while the use of *An Inquiry into Life* increased fourfold to a total of 5452. The use *An Ecological Approach* remained the highest of the three versions with its use increasing by 2191 to a total of 9402. Use of the second level course, *Interaction of Experiments and Ideas,* and *Laboratory Blocks* was unchanged while the slow learner materials, *Patterns and Process* revealed a marked decline in usage that parallels the reported decline in ability grouping.

In 1977–78 the BSCS teachers expressed greater satisfaction with their teaching facilities than earlier, while the same percentage, 94, in each study considered BSCS equal to or better than other materials. Ninety three percent of the BSCS teachers reported that the average student encounters either moderate or no difficulties with the materials. The most common difficulties reported in teaching BSCS biology, in descending order, are inadequate physical facilities, student distinterest and shortage of materials. There were no differences between BSCS and non-BSCS teachers in median years of experience (9), undergraduate credit hours in biology, and graduate hours in biology. The non-BSCS teachers reported more credit hours in chemistry. A greater percentage (48) of the BSCS teachers held advanced

degrees compared to 34% for non-BSCS teachers. This is comparable to the degrees reported in the earlier study. Slightly more than one-half the BSCS and one-third of the non-BSCS teachers have received training for teaching BSCS materials and that training was most frequently gained through attendance at NSF Summer and In-Service Institutes. *Modern Biology* is still the most commonly used text and was the choice of 130 of the 213 non-BSCS teachers.

MIGRATORY TRENDS IN KANSAS PLANTS. Thomas A. Eddy, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

This study assessed changes that have occurred in the distribution of selected herbaceous and woody components of the Kansas flora during the past century. Frank C. Gates of Kansas State University published maps in 1939 identifying thirty woody species with migratory tendencies and forty-nine maps of migratory herbaceous species in 1940. The migrational progress of each taxa during the past forty years was evaluated in 1979 by field searches in the counties on the leading edges of the direction of movement of each species and from plant distribution records in the 1977 Atlas of the Flora of the Great Plains. Nineteen woody species showed continuing migrations to the west, two to the east and three to the north. Twenty-four herbaceous species continued migrations to the west, eleven to the east, six to the north and five to the south.

EXPERIMENTAL STUDIES ON CEREBELLAR MATURATION IN LARVAL FROGS. Victor B. Eichler and Mary J. Edmundson, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208.

Several definite and well-described maturational changes occur in the cerebellum of larval frogs late in the premetamorphic period, resulting in an adult morphology very different from that in the premetamorphic larva. The present study was undertaken to relate the maturational changes observed in the cerebellum of *Rana pipiens* to one or more of these possible causal factors: (1) increasing age (time dependence); (b) functional connections to the hindlimbs, which are developing coincident with the cerebellar changes (functional dependence); or, (c) direct or indirect action of thyroid hormone on the cerebellum (hormonal dependence). Hypophysectomized larvae were used to look at the causal relationship between cerebellar maturation and increasing age; there was no significant difference in the size or the histological appearance of the cerebella of the operated animals compared to those of a corresponding developmental stage of control larvae from the same clutch of eggs. Larvae subjected to surgical amputation of the hindlimb buds at an early age tested whether functional neural connections to the hindlimbs were necessary for normal maturation of the cerebellum; the

brains of experimental animals were found not to be significantly different from controls as a result of the operation. Small thyroxine-cholesterol pellets, or pellets with only cholesterol, were implanted on one side of the hindbrains in two other groups of larvae, and right and left sides were compared within groups, between these experimental and sham-operated groups, and each with an unoperated control group. It is concluded that cerebellar maturation in this species does not appear to be dependent upon increasing age only, or upon functional hindlimb connections, but is affected by the presence of thyroxine, although possibly acting in an indirect fashion.

CHARACTERISTICS OF BULBUS CORDIS MECHANORECEPTORS IN THE POND TURTLE, *PSEUDEMYS SCRIPTA ELEGANS*. F. M. Faraci, M. A. Klotz, H. W. Shirer, and J. A. Orr, Department of Physiology and Cell Biology, University of Kansas, Lawrence, Kansas 66045, and J. W. Trank, Department of Physiology, University of Kansas Medical Center, Kansas City, Kansas 66103.

Previous work in our laboratory has shown in the turtle that afferent cardiac synchronous nerve traffic is carried in the vagus. It has also been shown that this species lacks a systemic arterial barostatic reflex. The purpose of this study was to find the origin of this nerve traffic and determine the sensitivity of these receptors to various stimuli. Vagal afferent nerve traffic was recorded in anesthetized artificially ventilated turtles. Nerve traffic from receptors that fired regularly during each heart cycle was recorded at or near the peak of ventricular and pulmonary systole at blood pressures that are normal for this species. Occasionally, receptors that fired irregularly were found, but these receptors could be made to fire during each heart cycle if blood pressure was increased slightly. Mechanical probing indicated that these receptors are anatomically located at the origin of the pulmonary artery, the bulbus cordis. If blood pressure was increased through saline infusion, the number of action potentials recorded per heart cycle increased. Intraventricular injection of veratridine (0.2 ml, 25 $\mu$g/ml) caused phasic nerve traffic to become continuous for several minutes and was accompanied by bradycardia. Lidocaine (0.1 ml, 10 mg/ml) injected into the ventricle immediately stopped nerve traffic. This work has provided evidence that mechanoreceptors in the bulbus cordis send signals to the brain related to fluctuations in pulmonary and ventricular blood pressure. These receptors may play some role in cardiovascular adjustments. (Partial support for this study was provided by Biomedical Science Support Grant #4893.)

RESPIRATORY EFFECTS OF UPPER AIRWAY $CO_2$ ADMINISTRATION IN THE AWAKE PONY. D. B. Fraser, J. A. Orr, H. W. Shirer, L. C. Wagerle, and R. C. DeSoignie, Department of Physiology and Cell Biology, University of Kansas, Lawrence, Kansas 66045.

Recent experiments conducted in our laboratory indicate that awake ponies increase their breathing during inspiration of low levels of $CO_2$, yet arterial blood $CO_2$ does not change significantly. These results have prompted us to investigate the effect of passing $CO_2$-rich air through the upper airways (upper half of the trachea, pharynx, and nasal region) of the awake pony to ascertain if "airway-only" $CO_2$ administration affects breathing. Twelve studies were conducted on six ponies in which $CO_2$ was injected into a tracheal cannula surgically implanted several days before the experiment. $CO_2$ was injected only during the first part of the animal's expiration to prevent any $CO_2$ from entering the lung and being absorbed into the arterial blood. During the treatments, airway $CO_2$ was raised 2%, 4% or 6% above the normal end-expired $CO_2$ level. Additionally a gas with $CO_2$, $O_2$, and $N_2$ concentrations similar to normal expired air (mixed gas) was injected into the trachea to test for the non-$CO_2$ effects of the maneuver. During $CO_2$ administration tidal volume increased, while respiratory rate tended to decrease resulting in no significant change in minute volume. Arterial blood $CO_2$ did not change but arterial blood $O_2$ tended to increase during $CO_2$ administration. In spite of the absence of a change in arterial blood $CO_2$ that would corroborate a change in alveolar ventilation, the data suggest that "airway-only" $CO_2$ administration may alter the breathing pattern of the awake pony. (Supported by a grant from the University of Kansas General Research Fund #3183.)

| | Control | 2% | 4% | 6% | Mixed Gas | Control |
|---|---|---|---|---|---|---|
| $V_T/M_2$ | 0.452 | 0.522 | 0.594 | 0.609 | 0.543 | 0.538 |
| (Liters) | 0.021 | 0.026 | 0.025 | 0.020 | 0.027 | 0.030 |
| $\dot{V}_E/M_2$ | 11.77 | 11.09 | 10.98 | 11.08 | 10.43 | 10.08 |
| (Liters) | 1.07 | 1.27 | 0.91 | 0.79 | 1.06 | 1.60 |
| $PaCO_2$ | 38.1 | 38.2 | 38.1 | 38.1 | 38.0 | 37.7 |
| (Torr) | 0.4 | 0.4 | 0.5 | 0.4 | 0.5 | 0.4 |
| $PaO_2$ | 88.2 | 91.2 | 92.6 | 94.2 | 87.6 | 84.2 |
| (Torr) | 1.1 | 1.2 | 2.6 | 2.4 | 1.4 | 1.7 |

Values are means (±SE)

SELENIUM IN GROUNDWATER NEAR GLADE, PHILLIPS COUNTY, KANSAS. Theodore R. Fritz, Gerald P. Grant, and Richard W. Ray, Kansas Department of Health and Environment, Hays, Kansas 67601.

Selenium concentrations that exceed the EPA maximum contaminant level of 0.01 mg/l for human consumption have been found in the Glade, Kansas municipal water supply. The effect of selenium on humans has been a matter of controversy, as have been results of tests on livestock. Studies

of selenium in various geologic and hydrologic settings in South Dakota show physical settings very similar to those around Glade. Strata that are present in both areas include Cretaceous Carlile Formation and Niobrara Chalk and Quaternary alluvium. At Glade, the Quaternary materials include the Sanborn Formation (which is mostly alluvium with some eolian silt), alluvial terrace deposits, and very recent alluvium along North Fork Solomon River. Water wells that penetrate the Sanborn Formation and/or terrace deposits tend to pump water with very low selenium content. In the South Dakota study, the Niobrara Chalk was found to have a very high selenium content; however, selenium was not released into water until the Niobrara was exposed to oxidizing conditions that produces more mobile selenates ($SeO_4^-$). This may be the situation at Glade since the Niobrara Chalk is at or near ground level in the area. Some other ion quantities in water samples analyzed for this study seem to vary either directly or inversely with selenium quantities. These include nitrate, iron, and manganese ions. Their association with selenium may be useful in predicting selenium contamination elsewhere.

TAXONOMIC STATUS OF SHREWS OF THE GENUS *BLARINA* (MAMMALIA: INSECTIVORA) IN KANSAS. Sarah B. George and Jerry R. Choate, Museum of the High Plains, Fort Hays State University, Hays, Kansas 67601.

The one species of the genus *Blarina* currently recognized in Kansas is *B. carolinensis*. Cranial measurements of short-tailed shrews from Kansas were studied; measurements were analyzed with basic univariate and multivariate statistics to assess geographic variation. Results of these analyses, plus preliminary karyotypic data, indicate the possible existence of two species in the state, *B. brevicauda* in northeastern Kansas and *B. carolinensis* nearly statewide.

FUEL WOOD FOR THE UNIVERSITY OF KANSAS STEAM GENERATING PLANT. Wayne A. Geyer and Gary Naughton, Department of Forestry, Kansas State University, Manhattan, Kansas 66506.

The Lawrence campus of The University of Kansas currently uses conventional fuels to fire its central steam plant. Alternatives to these scarce and high cost fuels would be solid waste material collected from the immediate area surrounding Lawrence, and wood to supplement the refuse. A four-year study to identify wood-supply sources has recently been completed by the Department of Forestry, Kansas State University. Comparative boiler fuel cost estimates (30 January 1980) of one million BTU delivered to the campus are as follows: municipal solid waste $0.88, urban tree salvage $1.11, sawmill residue $1.50, railroad ties $1.76, western coal $1.80, natural gas $2.20, "energy forests" plantation wood $2.20, No. 5 fuel oil

$4.50. All sources are less than fuel oil, but for other than natural gas, a new boiler system would need to be constructed. Plantations established exclusively for energy production would require about 700 acres of land to supply the wood for the campus steam plant.

UNIONACEAN MUSSELS OF THE WALNUT RIVER BASIN. Rose A. Hacker and Donald A. Distler, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208.

A survey of freshwater mussels (Bivalvia, Unionidae) was conducted in the Walnut River Basin from August 1978 to November 1979. Earlier surveys list a total of 22 species in the basin. In the present survey, representatives of 21 species were collected, complementing 20 of the species previously reported and adding one new species, *Proptera laevissima*.

Of living individuals, 85% were represented by *Amblema plicata, Quadrula quadrula, Lasmigona complanata, Anodonta grandis, Leptodea fragilis,* and *Lampsilis radiata*. The remaining 15% were represented by *Quadrula pustulosa, Uniomerus tetralasmus, Anodonta imbecilis, Proptera laevissima,* and *Lampsilis ovata*. Anthropogenic activities in the basin seem to be responsible for a reduction in the distribution and abundance of *Amblema plicata, Quadrula pustulosa, Lampsilis radiata, Lampsilis ovata, Strophitus undulatus,* and *Tritigonia verrucosa*.

The following species are thought to be extirpated from the basin: *Pleurobema cordatum, Truncilla truncata, Proptera purpurata, Ligumia recta, Obliquaria reflexa,* and probably *Lampsilis teres*. Proposed anthropogenic activities favor increased siltation, intermittency and pooling, reduced flow, and more frequent scouring by floods. Such habitat modifications probably will further reduce the number of species of unionid mussels in the Walnut River Basin.

THE DESIGN OF NUMERALS WHEREBY NUMERICAL VALUE DICTATES SHAPE OF THE NUMERAL AND CHANGE IN VALUE PRESCRIBES CHANGE OF SHAPE. Raymond C. Hall, Chemical Engineering Department, Kansas State University, Manhattan, Kansas 66502.

There is no apparent relationship between visual properties of either Arabic or Roman numerals (except "one" in Arabic and "one" through "four" in Roman) and the number of items which the numeral represents.

Would it not be possible to design numerals such that their value would be apparent through direct visual inspection rather than through rote memorization? Moreover, would it not be possible to invent a system of visual properties for numerals having characteristics such that, when one number is interreacted with another, the resulting change in value would prescribe changes in visual properties of the produced numeral?

This paper presents an approach to counting which leads to a logical

system of shapes of numerals to indicate value and develops the system to show how changes in values prescribe changes in shapes.

It is incidentally suggested that this approach to a numerals system would be especially useful in helping the development of the budding intellect as a youth struggles with the early stages of identification of numbers and with the learning of elementary arithmetic. Specifically it is suggested that the proposed system would eliminate the need for rote memorization in learning numbers by replacing the authoritarian "it is so because teacher says so" with a series of steps, each of which is amenable to logical development. In such an approach the emerging intellect would enhance his ability to use logic in learning rather than relying simply on rote memorization.

The concept of "empty" or "zero" and the concept of place value both develop naturally from the proposed concept of counting.

The developed system of numerals would be readily adaptable to use with electronic scanners.

The system falls naturally into any of several bases.

USE OF IDENTIFICATION ALGORITHMS TO DETERMINE RATE CONSTANTS FROM TIME-CONCENTRATION DATA. Peter Hamlet, Department of Chemistry, Pittsburg State University, Pittsburg, Kansas 66762; Gary McGrath, Department of Mathematics, Pittsburg State University, Pittsburg, Kansas 66762; and Deig Sandoval, Department of Chemistry, Pittsburg State University, Pittsburg, Kansas 66762.

Pulsed high pressure mass spectrometers follow the course of ion-molecule reactions by measuring ion concentrations as a function of time. Sometimes studies are performed on systems in which several reactions occur simultaneously. In order to sort out rate constants of individual reactions, we have developed algorithms to use on proposed reaction schemes. These algorithms are based on least squares techniques and have been tested on both simulated and experimental data.

THE DEVELOPMENT OF WATER QUALITY CRITERIA FOR AMMONIA AND TOTAL RESIDUAL CHLORINE FOR THE PROTECTION OF AQUATIC LIFE IN TWO JOHNSON COUNTY KANSAS STREAMS. Ralph H. Hazel, Johnson County Unified Sewer Districts, Shawnee Mission, Kansas 66202.

A study was conducted to determine water quality criteria for ammonia and total residual chlorine (TRC) for the protection of aquatic life in two streams in Johnson County, Kansas. The test streams selected were Mill Creek, and Cedar Creek. These parallel streams flow into the Kansas River and share similar watershed characteristics. However, unlike Mill Creek, Cedar Creek does not receive sewage treatment plant effluents.

The specific goals of the study were to determine water quality data for the streams, toxicity levels for selected test stream fauna, fauna response to artificially induced, stressed stream conditions, and subsequently develop criteria for ammonia and TRC.

The streams were sampled on a monthly basis and two diurnal studies were also conducted. Species indigenous to the streams were collected and 96 hour acute toxicity tests conducted with ammonia and TRC. A flow through diluter was constructed for this purpose.

Following the laboratory work, a test was conducted in Cedar Creek whereby ammonia was introduced for 24 hours. Test organisms were placed in cages in the stream and mortalities observed throughout the test period.

The paper will present the findings of this study. The author based his Ph.D. dissertation on this work at the University of Kansas. The research was supported by a two year grant from the Kansas Water Resources Research Institute.

A DESCRIPTION OF THE TRANSFORMATION METARHODOPSIN I $\rightleftharpoons$ METARHODOPSIN II IN BOVINE ROS BY CATALYSIS KINETICS. Carl S. Helrich, Department of Physics, Bethel College, North Newton, Kansas 67117.

In the dark reaction following illumination of the visual pigment Rhodopsin, the transformation Metarhodopsin I $\rightleftharpoons$ Metarhodopsin II seems to be that involved in the triggering of the retinal membrane thereby initiating the visual process. Flash photolysis measurements of this transformation in bovine rod outer segments have indicated that the reaction can be described by catalysis-type kinetics in which an intermediate complex (MX) consisting of Metarhodopsin (M) and a second component (X), possibly a phospholipid, is formed.

$$M_I + X \underset{k_2}{\overset{k_1}{\rightleftharpoons}} MX \underset{k_4}{\overset{k_3}{\rightleftharpoons}} M_{II} + X$$

In this scheme, the rate determining step is the combination of Metarhodopsin with the second component ($k_3 \gg k_2$; $k_4[M_{II}] \gg k_1[M_I]$). Experimental results of our laboratory are presented and shown to be consistent with the proposed scheme. It is also shown that the multiple exponential behavior attributed by other authors to the existence of multiple forms of Metarhodopsin I can be derived from this scheme. (This work was supported by the Deutsche Forschungsgemeinschaft and performed within the activities of Sonderforschungsbereich 160 "Eigenschaften biologischer Membranen" Aachen-Jülich-Düsseldorf.)

COAL LAND RECLAMATION IN SOUTHEAST KANSAS: STAGES OF DEVELOPMENT. Robert S. Hilt, Department of Social Science (Geography), Pittsburg State University, Pittsburg, Kansas 66762.

Coal land reclamation in Southeast Kansas has undergone three stages of development and awaits a fourth. The first stage of basic reclamation included early efforts by individuals, clubs, and state agencies to revegetate unleveled spoil banks and stock strip pits with fish. This first stage did not include land leveling prior to revegetation, typical of the pre-1960 era of reclamation in Southeast Kansas. The second stage of reclamation was that of early land leveling and economic pastureland development by private landholders. Some earlier efforts began prior to 1960, but most successful pasture reclamation of this period dates from 1960 to 1970. A third stage of reclamation consists of forced and voluntary coal company reclamation since the Kansas Reclamation Act of 1968, two Ozark Regional Commission projects, and recent private efforts. This stage is yet ongoing.

A fourth stage of reclamation is forecast. This stage would be one of national uniformity of standards and probable cost-sharing. Kansas owners of orphan (pre-1968) coal stripped land will most likely be forced to conform to federal standards to qualify for funds intended to reclaim more than 41,000 acres of land in Southeast Kansas. Legislation for this effort is the abandoned mine lands program initiated under the Surface Mining Control and Reclamation Act of 1977.

THE FAUNA OF ARGILLOTROPHIC LAKES IN SOUTH-CENTRAL OREGON. K. Charles Hunter, Department of Biology, Southwestern College, Winfield, Kansas 67156.

An intensive field study of the fauna of argillotrophic lakes was conducted in the summer of 1978 in Lake County, Oregon. Data from approximately 100 study sites was obtained. Most of the lakes are temporary bodies of water, lasting for 3–5 months (April–August). They are generally characterized by persistent and extreme turbidity, an absence of appreciable phytoplankton, a zooplankton association of low diversity, and in many cases high alkalinity and high conductivity.

Several different faunal associations dominated by Branchiopod Crustaceans were identified. Three species of the Notostracan, *Lepidurus*, were collected: *L. couesii, L. bilobatus,* and *L. lynchii.* Distribution and habitat requirements were investigated. Similar observations were made concerning 4 species of the Anostracan, *Branchinecta: B. dissimilis, B. coloradensis, B. mackini,* and *B. gigas.*

J. C. Jang, Department of Chemistry, Kansas State University, Manhattan, Kansas 66506.

The multiple photon unimolecular dissociation of the molecule, $CH_3CF_3$, and some organic esters were studied under irradiation by a powerful pulsed

$CO_2$ laser. Dependence of the reaction probability on laser power, fluence and pulse length were measured. Experimental results showed that the reaction probability $P(\phi)$, depends on the Nth power of the energy fluence, $\phi$, at low energy fluence where N is 4~6 depending on the molecule, i.e. $P(\phi) \alpha \phi^N$. The reaction probability showed a saturation effect at high energy fluence. The dependence of $P(\phi)$ on the laser power was negligible. The dependence of reaction probability on pressures of the parent and buffer gases also were studied. These experimental results were used to characterize inter- and intra-molecular energy transfer and to develop simple physical models for multiple photon laser induced unimolecular reactions.

DR. ALBERT ABRAMS, DEAN OF ELECTROQUACKS. Leland E. Keller, Department of Biology, Pittsburg State University, Pittsburg, Kansas 66762.

This paper reviews the technique of the most famous and controversial medical fraud of the early 20th century, Albert Abrams, M.D., who was supported by thousands of testimonials and followers. A blue ribbon committee assigned by the Scientific American Publishing Co. proved to the public that the Electronic Reactions of Abrams was a product of the practioner's mind. Abrams developed a medical diagnostic Rube Goldberg which consisted of a series of interconnecting devices which, when properly tuned, could diagnose the patient's disease. For the Electronic Reactions to be detected, a drop of the patient's blood was placed in one device; the patient was connected by way of skin electrodes to another device; and by adjusting the switches on all the devices the diagnosis was determined. In spite of world wide acclaim for the Electronic Reactions of Abrams, the committee of medical scientists and engineers concluded that the Abrams technique was "At best an illusion, at worst a colossal fraud." Slides showing the device in use and an original Abrams instrument will be presented.

ANTIOXIDANTS AS INDUCERS OF MACROSTOME FORMATION IN CILIATES. David C. Lennartz, Department of Physiology and Cell Biology, University of Kansas, Lawrence, Kansas 66045.

The phenomenon of macrostome formation leading to giant formation within the ciliated protozoa is a means whereby bactivorous forms may become carnivorous or even cannibalistic organisms. Previous research on this aspect of ciliate physiology has employed a selective feeding regime wherein *Blepharisma americanum* is induced to form giants after feeding on a series of prey organisms of increasing size. Other ciliates such as *Tetrahymena vorax* have been induced to form macrostomes by treatment of microstomes with a poorly defined "transforming principle" termed "stomatin." In the present research; the antioxidants d- -to- copheryl succinate (vitamin E); 2, (3)-Tert-butyl-4-hydroxyanisole (BHA) and 2,6-Ditert-butyl-

p-cresol (BHT) are used to induce giantism in *Blepharisma americanum* and *Tetrahymena vorax*. Concentrations covering the range $10^{-9}$ M to $10^{-4}$ M were found to be effective inducers of giantism in *Blepharisma americanum*. The most effective conditions for induction of the macrostome form are $10^{-4}$ M BHT or vitamin E @ 18–20°C and pH = 5.5–6.0. Under these conditions, 95% of the organisms treated are transformed into macrostomes within 6–8 hours. The first visible changes in treated cells occur 2.5–3.0 hours following addition of the antioxidants. Giant forms are observed 9–12 hours after antioxidant addition and remain in that form unless they are washed and resuspended in Chalkley's solution @ pH 5.5–6.0. Under these conditions, *Blepharisma* giants undergo 2 divisions and are thereby returned to normal size. This occurs over a three day period. Results obtained with *Tetrahymena vorax* are similar although the percentage of macrostomes formed is lower (30–40%).

EFFECTS OF A 24 HOUR AMMONIA INJECTION ON STREAM DRIFT AND BENTHIC STANDING CROP. Paul M. Liechti and Donald G. Huggins, State Biological Survey of Kansas, University of Kansas, Lawrence, Kansas 66045.

During the first week in July 1979, 1.4 mg/l un-ionized ammonia (average over 24 hours) was added to Cedar Creek, Johnson County. The field test, part of a study to establish water quality criteria for ammonia, included estimating changes in the standing crop and drifting organisms before and after the ammonia addition. Prior to application a 24 hour drift net sampling revealed a typical diel invertebrate drift pattern. Major constituents of the drift and most effected by the ammonia were the Diptera subfamilies Chironominae, Orthocladiinae and Tanypodinae; the trichopteran genus *Cheumatopsyche*; the mayfly genera *Baetis* and *Caenis*; the beetle genera *Dubiraphia, Stenelmis* and *Pelodytes*; the stonefly *Neoperla clymena*; and the amphipod *Hyallela azteca*. The 24 hour drift net sampling during the ammonia application indicated no change in the diel drift pattern. However, there was a pronounced increase in magnitude of drift and a slight shift in kinds of organisms present in the drift. Changes were also experienced in benthic standing crop estimates taken before and after the ammonia application. Since there was no change in the pattern of invertebrate drift, the ammonia concentration maintained in the stream was probably sublethal. Conversely, fish fry of *Noturus exilis, Notropus* sp. and *Etheostoma spectabile*, not normally found in drift net samples, were taken in large numbers during the ammonia application and were probably present due to toxic effects of the ammonia. Previous laboratory experiments with adults of *Notropus* and *Etheostoma* showed them to be sensitive to the levels of ammonia used in the stream.

NEURONAL CHANGES DURING ENERGY DEPRIVATION. Greg A. Looney and Nancy Ann Dahl, Department of Physiology and Cell Biology, University of Kansas, Lawrence, Kansas 66045.

The neuropathology of rabbit vagus nerves subjected to energy deprivation was examined. Longitudinal micrographs of the vagus axons following a no energy insult were analyzed to examine the response along individual axons. The vagus nerves were pulled into a multicompartmented perfusion chamber. The nerves were stimulated 5/sec as a no-energy-substrate Locke's solution (containing deoxy-D-glucose and saturated with $N_2$) was rapidly perfused across the nerve. Experiments were carried out at 37°C. After .5, 1, 2, and 4 hours the nerves were fixed, stained and embedded for E.M. analysis. The structure of the axons was examined in both cross and logitudinal section. Control axons were uniform in diameter and contained normal appearing microtubules and neurofilaments. We have reported that following 2 hours of anoxia the cross sectional area of the C fiber axons decreases. At 2 hours the axons in longitudinal section were smaller in diameter than the control axons, but uniform down the axon. The neurofilaments, microtubules and other organelles were present; however, the neurofilaments and microtubules were often clumped. In contrast, microtubules were often absent and the neurofilaments were tight packed in the smallest axons. Following 4 hours of energy deprivation we have previously reported that >50% of the axons shrink with <10% of the axons swelling but comprising most of the axonal area. At 4 hours logitudinal sections of axons showed that the axons were not uniform in diameter. Many axons were constricted in one region and ballooned at various points down the axon. There were few microtubules present in the 4 hour axons but neurofilaments were compacted into tight bundles in the constricted portion of the axons and fanned out where the constricted regions met the swollen sections. Inside the ballooned sections of the axons were numerous membrane vesicles (possibly swollen endoplasmic reticulum). Membrane vesicles were seldom seen in the shrunken portions of the axons. At various points along the membrane of the swollen axons there were breaks in the membrane. Membrane breaks were rarely seen in the constricted portions of the axons. It appears that the initial response to energy deprivation is shrinkage with swelling in isolated portions of the axons occurring later. Shrinkage may be due to washout of small particles by the perfusate and swelling at 4 hours may be caused by isolated lysosomal activity. (Supported by a Grant-in-Aid from the American Heart Association.)

CONCEPT OF THE NEBRASKA STATEWIDE ARBORETUM. Charles R. Maier, Department of Biology, Wayne State College, Wayne, Nebraska 68787.

During the early years of the present decade, the seed of an idea began to germinate at the Horticulture and Forestry Department of the University of Nebraska, Lincoln: the creation of an educational display of trees, shrubs, and other plants for all Nebraska's citizens to enjoy. As conceived by Dr. J. O. Young, Mr. Glen Viehmeyer, and Dr. Roger Uhlinger, it would involve numerous sites scattered through the state's 93 counties, and include public and private institutions, colleges, state agencies, private corporations and individuals. The kinds of sites would ultimately be for research, teaching, community involvement, and recreation, or to mark notable individual collections or outstanding specimens. The seed was nurtured mainly by these three and several associates, through its formation from 1974 to 1976. It emerged with the selection and dedication of several affiliated sites in 1977 and 1978, before the establishment of the Nebraska Statwide Arboretum Corporation in early 1978. There are now 16 affiliated sites, two others tentatively approved for membership, and several others under consideration. They are governed by a State Director (Curator) J. O. Young, with the Guidance of an Executive Board and advisory council headed by Chairman Wilbur Dasenbrock. Thus the concept of the Nebraska Statewide Arboretum has now come of age.

REPRODUCTIVE AND FATBODY CYCLES IN A KANSAS POPULATION OF THE COLLARED LIZARD, *CROTAPHYTUS COLLARIS* (SAY). Luis Malaret, Museum of Natural History, University of Kansas, Lawrence, Kansas 66045.

Study of reproductive and fatbody cycles of 162 specimens of *Crotaphytus collaris* from Wabaunsee County, Kansas, revealed that males use their fat reserves early in the season as shown by the decrease in mean fatbody lengths from May to early June: 9.64 ± 11.7 mm and 2.88 ± 6.4 mm respectively. The onset of fat deposition begins at the end of June and continues through July and August. Females show greater variation; yearlings use fat reserves more rapidly than older individuals (adults) as indicated by the mean fatbody values for each group during early June: 7.33 ± 8.1 mm (yr) vs. 20.57 ± 12.9 mm (adults). As in males, fat accumulation begins in late June.

Testes rapidly develop upon emergence of the males in spring and reach a peak in mean volume of 241.9 ± 137.5 $mm^3$ and 271.5 ± 154.5 $mm^3$ for late May and early June respectively. During late June and July testes regress to 120.7 ± 39.4 $mm^3$ and 86.7 ± 48.8 $mm^3$. Adult females begin yolk deposition of ovaries in spring and oviducal eggs first appear in late May. However, yearlings do not possess until late June. Egg deposition begins in late May and continues until late July. Reproductive activity in females is greatest in May and June with 80% and 91% of the individuals participating. In July it declines to only 57%. Of 62 females of age 1 year and older, 58 (94%) were reproductively active. All reproductive yearlings (N = 24) ex-

cept for one, produced only a single clutch. 18 (58%) of 31 adult females produced two clutches and 13 (42%) produced one. Clutch size, calculated by counting oviducal eggs, yolked follicles, corpora lutea and corpora albicantia is 7.56 ± 2.8 (N = 57) and was strongly correlated with snout-vent length (SVL) (r = .40, $P < .01$). Thirteen females contained oviducal eggs and the mean egg weight was 1.34 ± .25 g. A significant correlation between SVL and clutch weight was found (r = .63, $P < .05$) but none existed between SVL and mean egg weight, indicating that egg weight doesn't change in response to female size.

ITERATIVE EVOLUTION IN THE NORTH AMERICAN CENOZOIC. Larry D. Martin, Department of Systematics and Ecology and Museum of Natural History, University of Kansas, Lawrence, Kansas 66045.

Repetitive ecologic replacement of certain adaptive types of mammals has characterized the terrestrial fossil record in North America for at least the last 37,000,000 years. These replacements follow the extensive extinctions that help to define the boundaries of the "North American Land Mammal Ages" and that appear to be spaced at 2.3–2.4 million year intervals. The most recent of these extinctions occurred some 10,000 Y.B.P. at the end of the Pleistocene. Periods, each including three Land Mammal Ages, form a second set of repeating phenomena, which correspond closely in their timing to the sedimentary cycles proposed by T. M. Stout. Both the shorter and the longer repetitive events are also closely comparable in temporal spacing to the climatic cycles recognized by Van der Hammen in the Upper Cretaceous and Tertiary Pollen record of Colombia, South America. Repetitive changes of this sort may be a consistent attribute of the entire geological record.

SPECIES SURVEY FOR STEROL CARRIER PROTEIN USING IMMUNOLOGICAL METHODS. Kim E. McCoy, Jon L. Jordan, and Robert E. Barnett, Department of Chemistry, Washburn University, Topeka, Kansas 66621.

Sterol Carrier Protein, SCP, is a low molecular weight protein of 16,000 Daltons which binds many hydrophobic molecules such as cholesterol, bile salts, BSP and ANSA. SCP also enhances or is required for many microsomal enzyme reactions such as the last steps of cholesterol synthesis, bile acid hydroxylation and fatty acid activation.

The purpose of this paper is not to show the absolute presence of SCP in various animal species, but to demonstrate the immunological cross reactivity of these species with rat SCP.

Sterol Carrier Protein, purified to homogeneity from rat liver 105,000 × g supernatant was injected into adult rabbits and antiserum was obtained. A quantative assay for SCP was been developed using immunoelectrophoresis that is sensitive from 0.4 to 4 micrograms SCP.

By our method we found the SCP concentration to be about 7 percent of the total protein in both rat intestinal mucosa and liver supernatants and with no immunological indication of SCP in other rat organs. Assays from other animal liver homogenates for cross reactivity compared to rat liver gave the following results: mouse, 86%, gerbil, 85%; squirrel, human, goldfish, fruit fly, ring-necked pheasant all were undetectable for SCP reactivity. These results, together with the fact that reaction of SCP with iodoacetic acid abolishes immunological reactivity with antibody but does not decrease its ability to enhance selected microsomal enzymatic reactions, testifies to the fact that small alterations in SCP structure can mask its reactions with antibody.

WOLF SCENT MARKING DURING THE TIME OF BREEDING, PREGNANCY AND BIRTH. Anne S. Mertl-Millhollen, Department of Psychology, Fort Hays State University, Hays, Kansas 67601.

Field studies on wolves during the winter have shown a direct correlation between the presence of scent marking (RLUs) by pair bonded alpha male and female wolves and territorial ownership. All of these appeared necessary to reproductive success. The relative contribution of the alpha female's marks and the frequency of marking during other seasons had not been determined, but it was assumed that female wolves marked very seldom outside the breeding season.

In this study, two captive packs of wolves at the N.A.W.P.F. were observed from the beginning of the breeding season to shortly after the pups were weaned. RLUs were performed almost exclusively by the alpha male and female wolves. The alpha pair that bred scent marked far more frequently than did the pair that did not breed. They scent marked the most during the breeding season, least at the time of giving birth, and at moderate levels during the female's pregnancy and after parturition. The alpha female did only 20% of the marking, but her marks were sniffed the most frequently. The alpha animals did the most sniffing of marks in general, and 48% of their marks were over one another's marks (double marks). The alpha female continued her scent marking after the breeding season, and marking rate by the male and female alpha wolves was directly correlated throughout the period of this study. Thus, double marking by the alpha pair correlated with reproductive success but was not limited to the breeding season. It appeared to have the greater function of maintenance of the pair bond throughout the year.

THE OCCURRENCE OF NITRATES AND THEIR HEALTH SIGNIFICANCE IN DRINKING WATER. Dwight F. Metzler, Bureau of Water Supply, Kansas Department of Health and Environment, Topeka, Kansas 66620.

Renewed attention is being given to the presences of nitrates in drinking water, occasioned in part by the concern about nitrates in foods, and in part by the EPA administration of the Safe Drinking Water Act.

EPA has established a nitrate limit of 10 mg/l ($NO_3$-N), solely to prevent infantile methoglobenemia (nitrate cyanosis) which occurs only in susceptible infants of less than three months of age. The nitrate levels in Kansas surface water supplies have not changed significantly. The problem is in groundwater. Investigations in Kansas have not produced definitive, universally accepted conclusions as to the source of nitrate in groundwater and their introduction to well waters. However, the sources must be renewable. Nitrate deposits, buried organic material or peat deposits are not the source.

Drinking water is not a primary source of nitrate in the diet. Nitrates can be removed from the water by ion exchange, electrodialysis and reverse osmosis; but the costs are high, ranging from $15 to $60 per family per month. This expense is not justified. Methoglobenemia is a reportable disease in Kansas where one case, associated with a farm well, has occurred in 21 years. The nitrate limit is exceed in 41 community water supplies having a total population of 18,062. Of this group, 280 infants per year are exposed to water which exceeds the nitrate limit. The methods currently in use are adequate to protect the small number of infants exposed. If additional safe guards are required, other alternatives than treatment for the removal of the nitrates are available.

UTILIZATION OF DIETARY FATTY ACIDS BY BOBWHITE. Suzanne M. Middendorf and Robert J. Robel, Division of Biology, Kansas State University, Manhattan, Kansas 66506.

Bobwhite (*Colinus virginianus*) encounter dietary stress in severe winters when heavy snow and ice cover make food unavailable to ground feeders. Fat deposits are then metabolized for energy until sufficient food can be found. These fat reserves must be replenished to survive a subsequent dietary stress period. During lipogenesis, the fatty acid composition of avian depot fat is influenced by the physiological state of the bird, its environmental conditions, and the composition of the diet. Although it is useful to know what foods are being consumed during fat recovery and their influence on lipogenesis, analysis of gut contents or fecal matter does not indicate what birds have eaten in the preceeding several days. This study considers the determination of the fatty acid compositions of bobwhites and six food items as a potential tool for determining the previous diets of bobwhites.

STATUS OF *BLARINA* IN NORTHERN MISSOURI. Nancy D. Moncrief and Jerry R. Choate, Museum of the High Plains, Fort Hays State University, Hays, Kansas 67601.

Field work was conducted during the summer of 1979 to determine the

present status of *Blarina brevicauda* and *B. carolinensis* in northern Missouri and southwestern Iowa. Preliminary findings of this study are reported and compared with recorded ranges of *Blarina* in Missouri and Iowa.

BRONCHOPULMONARY ANATOMY OF THE COYOTE (*CANIS LATRANS*). E. E. Morrison and G. T. Hartke, Department of Anatomy and Physiology, Kansas State University; H. W. Leipold, Department of Pathology, Kansas State University, Manhattan, Kansas 66506.

The bronchopulmonary anatomy of the coyote (*Canis latrans*) was examined by gross dissection, radiographs, and vinyl plastic corrosion casts. In the coyote, the right lung has four lobes and the left lung has two. Each lobe is ventilated by a single lobar bronchus originating from the principle bronchus. The right and left cranial lobes are divided into cranial and caudal segments, the former being larger. The lobar bronchus of the middle lobe ramifies into dorsal and ventral segments. The accessory lobe consists of a cranial and caudal segment. The right and left caudal lobes consist of three larger ventral segments and four to five smaller dorsal segments. The lobes are supplied by a single pulmonary lobar artery. The arteries have a close relationship with the bronchi, and follow their ramifications closely. The lobar veins arise intersegmentally. They are formed by the union of segmental veins and run medial to the bronchi to enter the dorsum of the left atrium, as pulmonary veins. The coyote and domestic dog have similar bronchopulmonary anatomy. Branching differences are observed in the caudal segment of the right cranial lobe.

SARCOPTIC MANGE IN COYOTES. E. E. Morrison and S. R. Robinson, Department of Anatomy and Physiology, Kansas State University, Manhattan, Kansas 66506.

Six coyote pelts were collected from fur dealers and examined for gross and microscopic characteristics of mange. Square centimeter sections of skin were digested in warm 10% KOH, in addition, skin samples were prepared for SEM examination. Sarcoptic mange mites, *Sarcoptes scabiei* were observed and identified in both digestion and SEM preparations.

SOME BIOGEOGRAPHICAL CONSIDERATIONS OF A PREVIOUSLY UNKNOWN POPULATION OF *THOMOMYS BOTTAE* IN SOUTHEASTERN COLORADO. Michael P. Moulton and Jerry R. Choate, Museum of the High Plains, Fort Hays State University, Hays, Kansas 67601.

In 1978, a population of *Thomomys bottae* was discovered on Mesa de Maya, in southeastern Colorado. Morphometrics of this population are described, as are general habitat, soil and burrow characteristics.

THE DETERMINATION OF BORON IN PLANT MATERIAL USING HEATED VAPORIZATION ATOMIC SPECTROSCOPY. Joe D. Parli, Department of Chemistry, Emporia State University, Emporia, Kansas 66801.

A HVAA method for the determination of boron by reacting it with a KCl-HF mixture directly on a tantalum strip has been investigated. The residue of a dry ashed sample of plant material (wheat) was dissolved in a .1 M HCl solution. The optimum time and current settings were established. The results obtained by the proposed HVAA method were compared to those obtained using the official AOAC colorimetric method. These results showed the HVAA method (sensitivity 3ppb) to be better than the AOAC colorimetric method (sensitivity 100 ppb), with the HVAA method having a 100-fold linear concentration range, a comparable boron content in plant material with the AOAC method, and a faster analysis time.

EARLY MINING IN THE CHEROKEE-CRAWFORD COAL FIELD OF SOUTHEASTERN KANSAS. William E. Powell, Department of Social Science, Pittsburg State University, Pittsburg, Kansas 66762.

The earliest Caucasian settlers who settled in the two-county area during the 1840's and 1850's collected fragments of coal from outcroppings to meet their subsistent needs. Later crude implements were used to pry coal from continuous outcroppings. The first, small underground mines were short tunnels or "gopher-holes" dug norizontally into coal-seams exposed on slopes. The earliest strip-mining of shallow seams was primarily accomplished by teams of mules and horses pulling scoops or scraps that were guided by commercial miners. Shaft-mining began in the coal field in 1874 with the completion of a subterranean mine in central Cherokee County and spread into eastern Crawford County during subsequent decades. The first use of a steam-shovel in the excavation of coal in the nation occurred near Pittsburg, Kansas, in 1877 and launched the era of mechanized surface-mining in the United States and the world.

SOME SIGNIFICANT CONTRIBUTIONS TO EARTH SCIENCE BY ALEXANDER VON HUMBOLDT. John R. Ratzlaff, Department of Earth Science, Fort Hays State University, Hays, Kansas 67601.

Alexander von Humboldt (1769–1859) was a scientist of international stature for over fifty years. He emphasized the unity and coherence of nature, and this holistic presentation in his great work *Cosmos* overshadowed, perhaps, his many contributions in the separate fields of anthropology, astronomy, botany, climatology, geography, geology, geophysics, meteorology, oceanography, physiology, and zoology. Nevertheless, many of these contributions are significant and enduring, particularly the use of isolines to

show geographical variations of phenomena. Humboldt's topographical profile of the Iberian Peninsula revealed, for the first time, that the interior of Spain was a high plateau. His traversal and mapping of a natural waterway connecting the Orinoco and Amazon River systems confirmed the existence of a phenomenon which, theretofore, had been rejected by most European scientists. The effects upon the flow of springs, the sustained flow of streams, soil erosion, and floods produced by deforestation were illustrated by personal observation of these conditions in the Basin of Valencia in Venezuela. Humboldt and French botanist Aimé Bonpland spent eighteen months in the Andean highlands of Colombia, Ecuador, and Peru. Humboldt's investigations of the major volcanoes of Ecuador and Mexico convinced him of the importance of eruptive processes in the creation of mountain ranges; his recognition of the linear orientation of volcanoes led him towards the notion that eruptions occur along subterranean clefts in the earth's crust. His findings and ideas were based upon all available empirical evidence, much of it obtained by personal observation and meticulous readings with the finest scientific instruments of the day. Humboldt was expert with sextant, telescope and chronometer, barometer, thermometer, magnetometer, and eudometer.

CIRCADIAN PATTERN IN THE ANTIGONADAL ACTION OF MELATONIN IN SYRIAN HAMSTERS EXPOSED TO CONTINUOUS ILLUMINATION OR 20 HR LIGHT:4 HR DARK. Marco Recalde and John Parrish, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

Previous reports have shown that single, daily injections of melatonin prior to activity onset cause testicular involution in Syrian hamsters kept in a 14 hr light:10 hr dark (14L:10D) photoperiod, but are without similar effect in hamsters maintained under constant illumination (LL). The fact that LL exposure inhibits the normal circadian peak in pineal gland melatonin synthesis in hamsters, implied that a twice daily melatonin-injection scheme might resensitize the reproductive system to the antigonadal action of melatonin. This contention is supported by the finding that a statistically significant 28% decrease in testes weight occurred when melatonin (25 $\mu$g) was administered prior to activity onset, followed by a second injection seven hours later, when hamsters were kept in LL. In marked contrast, no inhibitory effects of melatonin were observed when the second injection was given either 10 hours or 14 hours after the preactivity injection. Hamsters exposed to 20L:4D, which received the first injection six hours before lights out and the second injection seven hours later (one hour after lights out), also showed a significant reduction in testes weight of about 20%. However, when the second melatonin injection was administered 10 or 14 hours after

the first injection, no antigonadal effects occurred. These data imply that the lack of an effect of single, daily melatonin injections is due to the loss of the endogenous melatonin peak induced by LL or 20L:4D. Twice daily injections of melatonin can resensitize the hypothalamic-hypophyseal-gonadal axis to the antigonadal action of a preactivity melatonin injection, but only if the second injection is administered near the normal time of the circadian peak in pineal gland melatonin synthesis.

A CRITIQUE OF THE EPA ALGAL ASSAY BOTTLE TEST. Danny C. Reinke and Frank deNoyelles, State Biological Survey of Kansas, University of Kansas, Lawrence, Kansas 66044.

The algal Assay Bottle Test (AABT) developed by the Environmental Protection Agency is currently being recommended as a sensitive test for toxic substances in aquatic ecosystems by its developers! The AABT, which was developed in the late 1960s and 1970s to evaluate the impact of changing nutrient levels, has proven to be an adequate tool for predicting the response of different waters to a given nutrient change and for predicting the amount of biomass the ambient nutrient level will support. Some ecologists may be surprised that a single organism test can adequately predict the response of an aquatic algal community to nutrients which may consist of 20–70 species. However, cirtually any unialgal test can predict the response of a community to nutrients because phosphorus and biomass are strongly correlated. The correlation between phosphorus and biomass is so strong and so consistant that EPA has determined that each $\mu$g/l of phosphorus supports 0.43 $\pm$ 20% mg dry wt/l of algal biomass. The strong correlation between phosphorus and algal biomass is also one of the reasons why the AABT does not work well for sublethal levels of toxic substances. Our studies indicate that the acute response to a sublethal level of a toxic substance is not a dramatic drop in biomass, but a temporary depression of carbon fixation, caused by a selective inhibition of sensitive species. This is followed by an atypical species shift as tolerant species rapidly expand into the gaps left by the sensitive species. This primary effect of sublethal levels of a toxic substance is caused by a change in the relative fitness of the algal species present and their ability to compete in the presence of the toxic substance. The chronic response to toxic substances is the establishment of an atypical dominate species as compared to unpolluted lakes in the same general area, with no reduction in total biomass. The only parameter measured by the AABT is total biomass and single organism tests can produce little information on competition and predation. Therefore the experimental design of the AABT specifically excludes the ability to measure the sensitive responses of the "real world" to sublethal toxic substances in aquatic environments.

THE INFLUENCE OF THE AMYGDALA AND LATERAL SEPTUM ON FEMALE SEX BEHAVIOR. K. J. Renner, E. S. Purcell, D. M. Quadagno, Department of Physiology and Cell Biology, University of Kansas, Lawrence, Kansas 66045; J. D. Bast, Department of Anatomy, Kansas University Medical Center, Kansas City, Kansas 66103.

Cycloheximide (CHX), an inhibitor of protein synthesis, has been intracranially placed to study the role and sites of estrogen action in the brain on the regulation of female sexual behavior. This drug was chosen because estrogen is thought to act at the level of the genome to initiate a series of protein synthetic steps which lead to the facilitation of sexual behavior. Data from our laboratory indicate various roles for neural sites in the control of female sexual behavior. The medial preoptic area (MPOA) and ventromedial hypothalamus (VMH) apparently exert a facilitatory effect on sexual behavior. CHX injected into these areas inhibits the action of high doses (3 $\mu$g) of exogenous estradiol benzoate (EB) in the ovariectomized (OVX) rat. When CHX was injected into the medial nucleus of the amygdala (AME) and cortical nucleus of the amygdala (ACO) or lateral septum (LS) no inhibition of sexual behavior was observed. The lordosis quotients (LQ)* of the animals in the AME, ACO and LS groups were 98%, 82% and 94% respectively.

The results from the experiment described above utilized a design in which CHX was injected into discrete brain areas and 6 hours later 3 $\mu$g EB was administered subcutaneously. The "suprathreshold" dose of EB was available to the entire brain including the MPOA and VMH. Thus, we could only demonstrate a lack of a primary facilitatory influence of the ACO, AME and LS in response to CHX treatment. When we administered "subthreshold" levels of 0.5 $\mu$g (a dose that does not induce sexual behavior in the OVX female), prior to CHX treatment, rats receiving CHX into the LS or ACO exhibited a mean lordosis quotient of 78% and 60% respectively. In contrast, the mean LQ of animals receiving the saline vehicle was only 3%. Animals which received CHX in the AME did not significantly differ from saline treated controls. It is tentatively concluded that the MPOA and VMH have a facilitatory effect on sexual behavior, whereas the LS and ACO have an inhibitory role. The role of the AME on sexual behavior, if present, has yet to be determined.

*Lordosis quotient (LQ) = number of lordotic responses by the female/10 mounts by the male $\times$ 100.

INDICES AND LOGARITHMS. Wanda S. Reves, Department of Mathematics and Department of Physics, Fort Hays State University, Hays, Kansas 67601.

The teaching of logarithms, long a Nemesis to high school mathematics teachers, can be justified and greatly simplified by borrowing some elemen-

tary concepts from group theory. By defining an isomorphism, known as an index, between the group of integers modulo p, a prime, under multiplication, and the group of integers modulo p-1, under addition, we can demonstrate all the properties of logarithms, and avoid the difficulties of computation inherent in using an infinite table. As an enrichment topic, this can produce some fascinating results from number theory, and can provide another channel for incorporating the computer into classroom use.

SEMI-LUNAR CYCLICITY OF NEUROTRANSMITTER-LIKE MATERIALS FROM *COLEUS BLUMEI* AND *PHASEOLUS VULGARIS*. Harry D. Rounds, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208.

*Coleus blumei* and *Phaseolus vulgaris* were raised and kept under a variety of conditions. Leaf samples (7 mm discs) were taken every day near to noon through a number of phases of the moon. Samples were extracted with 95% ethanol, taken to dryness and either frozen or resuspended in insect saline. Extracts were assayed for activity on the cockroach heart. Only cardioacceleratory activity was found and the amount of activity reached minimal levels shortly following new and full moon. Results with plant extracts were similar to earlier results with animal bloods (cockroach, mouse and human), but complementary to results with nervous tissue (cockroach). The current working hypothesis is that these cardioactive materials are "modulator" substances which, in these cases, are directly or indirectly mediating the effects of the relative positions of the earth, sun and moon.

A PROPOSED MODEL FOR EVALUATING THE EFFICACY OF ANTIPSYCHOTIC DRUGS. Daniel T. Ryan and Richard A. Sugerman, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208.

Recent studies of the brain chemistry in reptiles indicate that there are close similarities between reptiles and mammals. Therefore, a novel approach for the evaluation of the efficacy of antipsychotic drugs was tested using reptiles as the experimental animal. The reptiles tested were male and female *Crotaphytus collaris*, western collared lizards. Testing consisted of monopolar stimulation with biphasic square wave pulse pairs (50 Hz, 2 msec, 0 to 620 $\mu$A). The stimulus was delivered in or near the nucleus profundus mesencephali (NPM). Animals were tested for evoked gular extension and/or mouth opening, both being components of agonistic behavior. A baseline for evoked behavior was determined by injecting the animal with saline (IM), allowing one hour of recovery time, and then electrically stimulating the animal at the threshold level every half hour for a total of seven stimulations. This baseline served as the control. The animals then received low and high dosages of three antipsychotic drugs (i.e., Thorazine, Haldol,

Reserpine) and were tested once more using the same regimen for evoked behaviors in comparison to baseline values. In this model no consistent dimunition of response was noted utilizing any of the three drugs.

SEEDLING SURVIVAL OF *SUAEDA DEPRESSA* AT BIG SALT MARSH. Steven G. Saunders and Arther L. Youngman, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208.

A study of seedling survival of the annual succulent halophyte *Suaeda depressa* (Chenopodiaceae) was conducted during the spring and summer of 1978. The purpose of the study was to determine (1) patterns of seed germination and seedling establishment, (2) range of soil salinities among *Suaeda depressa* microsites during the growing season, and (3) relationships between seedling mortality and certain environmental parameters—specifically soil moisture, soil salinity, rainfall and temperature. Among twelve microsites there were 2543 seedlings of where four seedlings survived through the end of the study in late September. Salinities, based on salt content of soil at field moisture capacity, ranged from 0.44% to 5.48%. Considerable differences in patterns of soil salinity and seedling mortality were noted among microsites. Of the four sites with the longest record of seedling survival, there were indications at three sites that increases in soil salinity was responsible for seedling mortality. At the fourth site, with over twice the seedling density of any other site (3.97 seedlings $in^{-2}$) seedling competition or some factor other than salinity appeared to be responsible for early seedling mortality.

FLUORESCENT NUCLEOTIDES FOR THE STUDY OF GENE TRANSCRIPTION. J. G. Schlageck and L. R. Yarbrough, Department of Biochemistry, University of Kansas Medical Center, Kansas City, Kansas 66103.

A new class of fluorescent nucleotide analogs which contain the fluorophore 1-aminonaphthalene-5-sulfonate attached via a $\gamma$-phosphoamidate bond has been synthesized. These derivatives are good substrates for *Escherichia coli* RNA polymerase with only slightly increased $K_m$ values and with $V_{max}$ values about 50 to 70% that of the unmodified NTPs. They are also substrates for eucaryotic RNA polymerase II, however, they are used much less effectively than the unmodified NTPs. Both the purine and pyrimidine analogs have fluorescence emission maxima at 460 nm. The fluorescence of the pyrimidine analogs is quenched; cleavage of the $\alpha$-$\beta$-phosphoryl bond of the UTP analog produces about a 14-fold increase in fluorescence intensity at 500 nm. This alteration provides a sensitive and precise means for continuous monitoring of transcription. Under appropriate conditions one can detect the utilization of less than 1 nmol of nucleotide. Since the spectroscopic techniques measure nucleotide utilization they

can be used in conjunction with measurements of incorporation of radiolabeled precursor such as [$^3$H]UTP into acid-insoluble material to determine whether significant amounts of acid-soluble oligonucleotides are formed. In addition, they should prove useful for both steady-state and rapid kinetic studies of model reactions for RNA chain initiation and elongation.

FOSSIL VERTEBRATES IN THE SPEISER SHALE, LOWER PERMIAN OF KANSAS. Hans-Peter Schultze, Museum of Natural History, University of Kansas, Lawrence, Kansas 66045.

Late Paleozoic sediments in Kansas are characterized by cyclicity. Marine invertebrate fossils clearly indicate the presence of a shallow sea in Kansas during the Lower Permian. Fossil lungfishes and amphibians occur abundantly in restricted horizons in Lower Permian rocks in Kansas. Sometimes these vertebrate fossils are associated with burrows, while often they are not. Most of these vertebrate fossils are closely related, if not identical, to contemporary fossil vertebrates of Oklahoma, Texas, and New Mexico. So far, one new genus, *Acroplous*, and one new microsaur species have been identified from the large number of Lower Permian vertebrate fossils in Kansas. This new microsaur species belongs to the genus *Euryodus* within the family Gymnarthridae.

EFFECT OF HEPATOCARCINOGENS ON ADENINE PURINE NUCLEOTIDE CYCLE ENZYMES FROM ISOLATED PARENCHYMAL CELLS. Scott Morrical, Ellen Lewis, Marie Butler, and Larry Smith, The H. L. Snyder Research Foundation, Winfield, Kansas 67156.

Changes in the activity of SAMP lyase, AMP deaminase and SAMP synthetase from rat liver that have been subjected to hepatocarcinogens have been studied. Two of these three enzymes (which make up the adenine purine nucleotide cycle) exhibit an increased activity under these conditions, namely SAMP lyase and AMP deaminase while the third, SAMP synthetase shows no increase to even reduced activity in some cases.

We attempted to determine if these changes were a product of changes in cellularity by isolating parenchymal cells from both control and treated animals and determining the activity of these enzymes in the isolated cells. Three carcinogens were used, i.e., 3′-methyldimethylaminoazobenzene (3′-Me-DAB), thioacetamide and 2-acetylaminofluorene (2-AAF). When diets containing 0.06% 3′-Me-DAB were fed for 7 weeks, there was an initial rise in both total units per cell and specific activity of SAMP lyase and AMP deaminase by the fifth week which was followed by a gradual decline by the seventh week. Specific activities remained above controls throughout the seven week period. SAMP synthetase showed little significant change in specific acitivity and a definite decrease in units/cell by the seventh week. There was also a noticeable decrease in protein per cell throughout the

feeding experiment accounting in part for the increased specific activity. Thioacetamide gave somewhat similar results as 3′-Me-DAB but 2-AAF gave no significant change by the seventh week.

When thioacetamide was administered by injection, results similar to those of the feeding experiment were obtained. Ethionine was also used in these experiments but no significant change occured.

These data indicate that most of the increased specific activities in SAMP lyase and AMP deaminase can be accounted for by intracellular increases and/or stabilization of these enzymes as opposed to selective cellular proliferation favoring these particular enzymes. Further work is planned i.e., similar studies on nonparenchymal cells to confirm these conclusions.

REEVALUATION OF THE PHYLOGENETIC POSITION OF THE PTYCHODONTIDAE. J. D. Stewart, Department of Systematics and Ecology and Museum of Natural History, University of Kansas, Lawrence, Kansas 66045.

Until the mid-20th century, paleoichthyologists universally believed that the affinities of the Ptychodontidae were with the batoid neoselachians, because of the durophagous dentitions which these two groups share. However, Casier (1953) grouped *Ptychodus* with *Heterodontus* (which he thought to be a hybodont) because of the arrangement and morphology of their dentitions. Patterson (1966) argued for a close relationship between *Ptychodus* and the hybodont *Hylaeobatis*. He also expressed doubt about reports of *Ptychodus* vertebrae published by Woodward (1912) and Canavari (1916), because they had never again been found with *Ptychodus* remains in European or North American Cretaceous deposits. A recently collected, well preserved specimen of *Ptychodus mortoni* (University of Kansas Vertebrate Paleontology no. 59041) proves that this genus does, in fact, possess calcified vertebrae. They are quite compressed and measure 63 to 65 mm in diameter. Recent phylogenetic analyses by Compagno, Reif, Maisey, and Schaeffer & Williams concur that all living sharks and rays (including *Heterodontus*) are members of the monophyletic Neoselachii, united by synapomorphies including the presence of calcified centra. Since *Ptychodus* shares this derived state, it must be regarded as a neoselachian and not as a hybodont, unless one were to postulate the multiple derivation of calcified centra. *Ptychodus* does not share the pectoral modifications synapomorphic for the batoids, nor is there evidence of a synarcual. There is no indication of calcified centra in *Hylaeobatis*. Since no evidence exists to suggest it is not a hybodont, it probably should be removed from the family Ptychodontidae.

OBSERVER EFFECTS AND DISPLACEMENT ACTIVITY IN *ANOLIS SAGREI*. Richard A. Sugerman, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208.

The relative timidity of lizards has until recently been anecdotal rather than based on experimental data. Sugerman and Hacker (J. Herp., in press) presented evidence that collared lizards significantly decreased their movements in response to an observer who was discernible. This article only reported on movement between spaces. This line of inquiry was expanded to study the effects of an observer on a lizard species that has been reported to be relatively insensitive to an observer and to record seven indices of activity: pushups, bobs, gular extension, short movements, chasing, running, and jumping. Four males and one female *Anolis sagrei* were tested. Animals were observed in a test cage for ten hours. The observer was visible to the animals for five hours and concealed behind a one-way mirror for five hours. All the indices except bobs tended to decrease when the observer was visible. The number of pushups decreased significantly (Wilcoxin matched-pairs signed-ranks test, $n = 9$, $T = 6$, $P < 0.025$). A discernible observer does affect the activity of *Anolis sagrei* and, therefore, covert techniques are recommended during behavioral experiments. In addition, the bobs appear to be related to a high level of excitation in the animals and should probably be considered, at least under these circumstances, as displacement activity.

LIBYAN DESERT GLASS: 1979 EXPEDITION. James R. Underwood, Jr., Department of Geology, Kansas State University, Manhattan, Kansas 66506; Robert Giegengack, Department of Geology, University of Pennsylvania, Philadelphia, Pennsylvania 19104.

During a five-day period in June 1979, the distribution area of Libyan Desert glass in SW Egypt was studied and samples of Nubian Sandstone, dune sand, and Libyan Desert glass were collected.

The largest pieces of glass (15–25 cm in maximum diameter) seem to be associated with poorly exposed boulders of Nubian Sandstone that, on Landsat images, appear to be coincident with a vague, indistinct elliptical shadow 12 × 8 km visible in three of the corridors between the nearly NS trending linear dunes characteristic of that part of the Sand Sea.

A 593-g, spoon-shaped, nickel-iron meteorite, 9.5 cm long and 6.6 cm wide, was recovered from the southern part of the distribution area of the glass at lat 25°09.5′N, long 25°35.1′E. Delicate microscopic ablation ridges on the convex side of the meteorite indicate that the residence time on Earth has been only a few hundred to a few thousand years (Alexander Bevan and Robert Hutchison, personal communication, 1979). If the fission-track anal-

yses that dated the glass at 28.5 m.y. (Gentner, Störzer, and Wagner, 1969; Störzer and Wagner, 1971) are valid, there can be no connection between the meteorite found in 1979 and the origin of Libyan Desert glass.

At lat 25°8.0′N long 25°35.3′E, a few kilometers SSE of the meteorite locality, a small, pointed handaxe made of Libyan Desert glass was discovered. The handaxe is 12.1 cm long, 6.0 cm wide, 3.9 cm thick, weighs 180 g, and is most likely a late Paleolithic (Acheulean) artifact (Derek Roe, personal communication). It is the first Acheulean-like handaxe to be discovered that was fashioned of Libyan Desert glass.

Artifacts of the Paleolithic Aterian cultural tradition abound; they are concentrated on the margins of two occurrences of old playa lake sediments that appear to pre-date the great linear dunes (seifs). These younger artifacts are composed both of Libyan Desert glass and siltstone of the Nubian.

AN EXPERIMENTAL STUDY OF BROWNIAN MOTION IN THE LIMIT OF SMALL TIME INTERVALS BY MEANS OF AN IDEAL GAS SIMULATOR. Henry Unruh, Physics Department, Wichita State University, Wichita, Kansas 67208.

A simulator of an ideal gas and its use for the study of Brownian displacements in the limit of small time intervals is described. The study was carried out to identify either the Einstein or Ornstein formula as best describing Brownian motion. The results are consistent with the Ornstein formula rather than the familiar Einstein formula.

ADENOSINE TRIPHOSPHATE AFFECTS GROWTH AND MORPHOLOGY OF *TRYPANOSOMA CRUZI*. Gail Walter and Eugene C. Bovee, Department of Physiology and Cell Biology, University of Kansas, Lawrence, Kansas 66045.

Adenosine triphosphate (ATP) is known to affect motile mechanisms of most cells and serves as a precursor of cyclic adenosine monophosphate (cAMP), but little has been done to determine how ATP affects growth and morphogenesis of protozoa, particularly parasitic protozoa. Our preliminary studies, using the dicalcium salt of ATP, with *Trypanosoma cruzi* (the Yaeger Corpus Christi strain) show a stimulus of growth at $1 \times 10^{-4}$ to $1 \times 10^{-3}$ M ATP added to the growth medium. Control populations peak and decline in about 5 days, while ATP treated populations continue to grow in greater populations for 7 to 10 days. Also, many organisms in the ATP stimulated cultures adopt the shortened trypanosome form thought to be infective for the human host. However, at the lower concentration of $1 \times 10^{-5}$ M ATP, many organisms contract, become round, shed the flagellum and take the amastigote, histozoic form. These morphogenetic changes at specific concentrations of ATP may have implications for the penetrance of the parasite

into host tissue and the assumption of the rounded state by the amastigote histozoic form in the cardiac tissue of the human host. (Supported by the Graduate Teaching Fund of the Physiology and Cell Biology Department, University of Kansas.)

SUBSURFACE GEOLOGIC STUDY OF THE LOWER PERMIAN HUTCHINSON SALT IN KANSAS USING AUTOMATED METHODS. W. Lynn Watney, Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66044.

Salt (halite) deposits of the Hutchinson Member of the Wellington Formation (Lower Permian) cover 37,000 square miles (96,000 km$^2$) in the Kansas subsurface occupying a volume of some 1100 cubic miles (4600 km$^2$). This salt deposit represents an important economic resource for the state, but also is the cause of natural pollution of groundwater and formation of solution sink holes. Thus a geologic understanding of this deposit is essential.

Geophysical log interpretation is considered the most abundant and accurate means of characterizing the salt. The last geophysical log study of the Hutchinson salt was conducted in the mid-'50s by the Kansas Geological Survey. Since then the log base has grown considerably along with an improvement in quality.

The objective of this study is to reevaluate the extent and quality of the entire Hutchinson salt through maps and cross sections and to describe the stratigraphy of the Wellington Formation. One core, taken completely through the salt, was described and integrated to log response. Sixty-two salt samples were analyzed for bromide concentration to assist in interpreting the origin of the salt and recognition of cyclicity. Thirteen stratigraphic measurements were made on each of nearly 4000 geophysical logs. When possible at least five wells were included per township (36 mi$^2$). Data were entered into a computer in which necessary calculations, error analyses, and editing were made prior to map generation.

Twelve different maps describing the salt and associated strata were contoured by the computer at a scale of 1:500,000 on a standard Lambert conformal conic projection using Surface II and Calcomp programs. After minor changes in the final copy are made these maps are suitable for publication.

The maps and cross sections reveal many details of the structural and depositional configuration of the evaporite basin including two major diachronous depocenters of the salt which illustrate the regressive nature of sedimentation in the upper Wellington Member. Also very apparent is the regional variation in anhydrite occurrence reflecting rather uniform changes in the dissolved salt concentration gradients of the brine body which precipitated the salt.

THE TEMPORAL CHANGES IN A FEEDLOT DRAINAGE LAGOON. T. L. Wenke and J. C. Vogt, Department of Biology, Fort Hays State University, Hays, Kansas 67601.

The temporal changes in a feedlot drainage lagoon with a predominance of the purple sulfur phototrophic bacterium, *Thiopedia rosea*, were investigated. At monthly or bimonthly intervals over a three-year period, the lagoon was monitored for pH, temperature, dissolved oxygen, sulfide, sulfate, ammonia, and alkalinity concentrations. Since attempts to culture *Thiopedia* have been unsuccessful, protein and bacteriochlorophyll were assayed to indirectly quantify its presence. The annual surface protein and bacteriochlorophyll concentrations peaked during the fall months. The surface bacteriochlorophyll levels tended to parallel the pH and alkalinity and during the fall months, when *Thiopedia* was most numerous, the pH was 8.2 or greater. The concentrations of bacteriochlorophyll, surface protein, and surface sulfide declined during 1979. Above average moisture during 1979 resulted in a 2.5-fold increase in depth of the lagoon; thus, the 1979 measurements are probably indicative of this dilution effect rather than the diminution of *Thiopedia*. Dissolved oxygen was also higher during 1979, although during the first two years the lagoon was essentially anaerobic.

*Thiopedia rosea*, which has a low tolerance for hydrogen sulfide, is capable of using hydrogen sulfide as an electron source and oxidizing it to sulfate. Surface sulfide levels, which increased over the winter and early spring, were rapidly depleted with the onset of the "fall bloom." The most striking pattern to emerge was the marked increase in the sulfate concentration each fall and winter. The elevated sulfate levels resulted from the *Thiopedia* "bloom" and the decreased metabolic rate of the sulfate reducers.

GEOLOGY AND STRUCTURE OF THE FARMINGTON "COMPLEX" (PRECAMBRIAN) OF NORTH CENTRAL UTAH. Robert W. Webster, Department of Earth Sciences, Fort Hays State University, Hays, Kansas 67601.

The middle Precambrian Farmington "Complex" crops out approximately 18 miles north of Salt Lake City, Utah, in and around Farmington Canyon. The "Complex" mainly consists of migmatitic gneiss, quartzo-feldspathic schists and progressive green schists; however, other metamorphic and igneous rocks are also present.

The structure of the Farmington Canyon area is intimately related to three series of folding. The first folds, $B_1$, are small, tight, isoclinal and ptygmatic folds with or without axial plane foliation. These folds are Precambrian in age. The second series, $B_2$, are major east-west trending folds and are thought to be late Cretaceous to early Tertiary (Early Laramide) in age. The

Farmington Canyon Antiform, the main structural element in the area, belongs to this series. The youngest series, $B_3$, are broad gentle north-south trending folds and are probably early Tertiary (Late Laramide) in age. These latter folds form an anticlinorial structure across the frontal Wasatch uplift.

GEOCHEMISTRY OF NATURAL WATERS IN THE KONZA PRAIRIE. Donald O. Whittemore, Lawrence R. Hathaway, Truman C. Waugh, and O. Karmie Galle, Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66044; G. Richard Marzolf, Division of Biology, Kansas State University, Manhattan, Kansas 66506.

Springs occur in several Permian limestones and dolomitic limestones separated by shales in the main watershed of the Konza Prairie, a research natural area in the northern Flint Hills, Riley County, Kansas. Predominant dissolved constituents in the spring waters from 6 different carbonate units are Ca (81–133 mg/l), Mg (19–30 mg/l), Na (6–9 mg/l), $HCO_3$ (308–369 mg/l), $SO_4$ (37–197 mg/l), and $SiO_2$ (10–14 mg/l). Concentrations of K, Sr, Cl, F, and $NO_3$ fall within the range 0.1–4 mg/l, while Ba, $PO_4$, and B vary within 0.04–0.15 mg/l. The chemistry of the springs is controlled mainly by solution of calcite, dolomite, and thin gypsum layers or small amounts of gypsum nodules or crystals within the strata. Sulfate concentrations have the greatest range of all major constituents in samples collected during the same hydrologic conditions. Variations in the $SO_4$, Ca, and Mg concentrations in a spring are inversely correlated with its discharge, and are caused by varying amounts of recharge from infiltrating precipitation; greater amounts of recharge dilute the groundwaters resulting in lower concentrations of constitutents. The chemistry of the baseflow in the main stream largely reflects a mixture of the spring waters in the watershed. Higher nitrate concentrations in the waters from the lowest spring in the watershed and the stream below this aquifer (3–5 mg/l compared with 0.1–0.8 mg/l in higher springs), might be caused by animal wastes leached in the past into groundwaters in the lower part of the watershed. The general chemical character and compositional variations of natural waters in the Konza Prairie are similar to those in another area of the northern Flint Hills in Pottowatomie County, Kansas.

PARENTS ATTRACT PREDATORS TO THEIR NESTS. Jodie Zimmerman, Steven J. Haug, Glenda A. Stark, Cary J. Herl, Susanne M. Voda, and Daniel E. Bowen, Benedictine College, Atchison, Kansas 66002.

Predation on 25 greater prairie chicken (*Tympanuchus pinnatus*) nests, located in the Kansas Flint Hills, was significantly greater during incubation than egg laying. All known nest predators were nocturnal and females attend their nests at night only during incubation, but never during egg laying. Thus

we conclude that the females rather than their eggs attract the predators. These data support part of Skutch's watchful predator hypothesis that states clutch size is limited if parents attract predators to their nests.

CHANGING STRUCTURE OF THE BEEF INDUSTRY IN KANSAS. Charles E. Bussing and Hubert Self, Department of Geography, Kansas State University, Manhattan, Kansas 66506.

Numerous changes have swept our society in the period since World War II. The population explosion, coupled with regional shifts in population, has not only created a much larger market to be supplied, but has also led to new production and consumption patterns. Incomes and standard of living have increased rapidly. These changes have had a great effect on agriculture in general and upon the livestock sector of the economy in particular.

The emergence of the commercial feeder and the rapid expansion in the volume of cattle finishing have been accompanied by substantial changes in the overall structure of the industry. Terminal markets have declined in importance, and a decentralization of packing-house facilities has occurred. The forces leading to change in the structure of the cattle industry have assumed many forms, and are likely to continue as the industry seeks now levels of efficiency.

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# The Great Blue Heron in Kansas

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## ABSTRACT

The distribution of and number of nests in the colonies of the great blue heron, *Ardea herodias* Linnaeus, in Kansas was checked annually from 1952 to 1962 and in 1973 and 1978. These nesting colonies are distributed statewide with heaviest concentrations in the Flint Hills. During dry weather cycles the average number of nests per colony dropped and increased during normal or wet years. The greatest number of nests recorded was in 1978 when there were 3075 nests in 94 colonies. The primary trees used are sycamores in the east and cottonwoods in the west. Life habits of herons during the nesting season were carefully observed and recorded on regular visits. This was accomplished from a blind placed where it would not disturb the birds but enabled observation into 45 nests. Nest construction, mating, incubation and care of young were the main topics observed.

## KANSAS PHYSIOGRAPHY

Kansas is located in a transition zone between the plants and animals of the eastern and western states and of the northern and southern states. About one-third of the way across the state from the east the Flint Hills extend from north to south and separate the tree-covered hills in the east from the plains and prairies of the west. In general, the Flint Hills are open rangeland, but the valleys have many springs, creeks and rivers edged with trees and there are numerous farm ponds containing fish, crayfish, frogs and some snakes. This is an ideal situation for a heron nesting site. To the west, the land flattens out, the soil becomes more sandy, the trees more sparse and the surface water not as common so the herons could not be expected to nest there in abundance. However, there are a few rivers, creeks, farm ponds and Federal Reservoirs for feeding grounds and with enough nearby trees to serve as nesting sites.

The state is divided into the Kansas River drainage system on the north and the Arkansas River system in the south, but there is little significant difference in the physiography of the two areas.

## METHODS

Naturally, the colonies were not all discovered the first year but the information was accumulated by many miles of travel and with the help of other people. Most of the travel was done during the winter because the colonies are easier to see and as they were found they were given a number and added to the list.

Beginning in December 1952 the known colonies were visited and the legal description of the location recorded on a card for that colony. In addition, the course of the stream, the relative location and species of trees used and the number of nests in each tree were charted on that card. The colonies in each county were designated by a number in the order in which they were first visited.

During the 11 year period between 1952 and 1962 all known colonies were visited and the information recorded on individual cards. The number of nests might be used as an indicator of the number of breeding birds, but this is only an indicator as a sturdily built nest will last through a second winter without being repaired. This is uncommon because the material of an unused nest is taken by the nesting birds and no unused nest in an active colony was known to have persisted into the third year. In two colonies a summer check showed the number of nests actually used was one nest greater than the winter count showed. However, in another colony where a summer check was not made, additional nests were added after the young had fledged.

For ease of comparisons, the state was divided into an eastern one-third, the range of the sycamore, and a western two-thirds where the cottonwood is the principal large tree. These two areas were then divided into north and south sections according to the Kansas and Arkansas river drainage systems.

Because of the cost and time consumed the counts were discontinued after 1962 with plans for a count in 1972 but because of adverse road and weather conditions this was postponed until 1973. Many of the 1973 and 1978 counts were made by Stanley Roth, Jr., biology teacher at Lawrence High School.

## DISTRIBUTION AND DURATION

There are no large areas in Kansas where a colony has not been located (Fig. 1), however, these map dots may be misleading. For instance, Ellis County shows 6 dots but Table 1 shows that only 3 of these have been active at the same time, whereas, the 11 colonies in Chase County were all used during several successive years. In 1973 there were 7 active colonies in Chase County with a total of 292 nests while a single colony in Sedgwick County had 235 nests. The third largest number of nests in a county was in

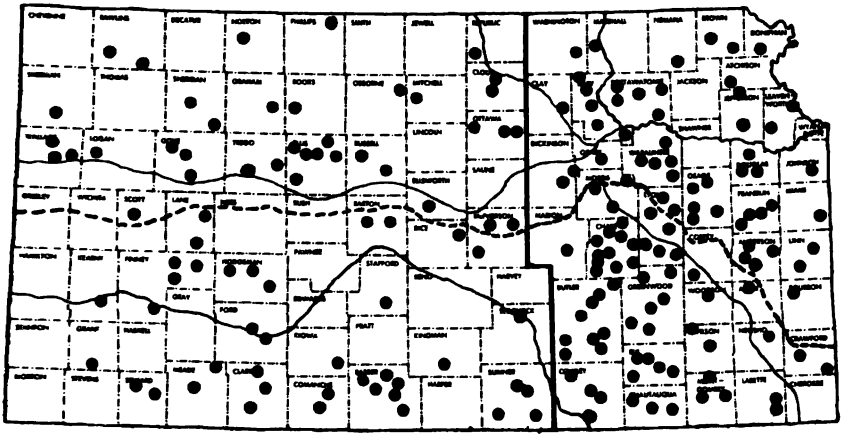


Fig. 1. The location of all known active and abandoned great blue heron colonies in Kansas as of 1978. The east-west dotted line indicates the divide between the Kansas and Arkansas river drainage areas. The north-south solid line divides the eastern (sycamore) area from the western (cottonwood) area.

Butler County where 5 colonies had 178 nests. The fourth largest was in Pottawatomie County (3 colonies, 151 nests) and the fifth largest was a single colony in Geary County with 149 nests. The greatest number of nests in one tree was 49, a sycamore in Pottawatomie No. 2 in 1953 and the same tree had 43 nests in 1973.

The eastern area has more colonies, more nests, greater size of colony and a larger percent of the total nests (Table 2), but the largest individual colony is in Sedgwick County in the western section. In 1962 and 1973 the southern half of the state had more colonies and a greater number of nests than did the northern half (Table 3). In 1978 the northern part had the most colonies and the difference between the number of nests in the two areas was very slight. The percent of the total nests has increased in the northern part and decreased in the southern part indicating the heron population is moving north.

Table 1 shows the life of a colony may be quite short or it may last for 50 or 60 years and in several cases a site was abandoned for a few years to be reestablished later. A 26 nest colony established in 1957 decreased to 8 nests in 1958 and was abandoned the third year.

Little is known concerning most of the colonies prior to 1952 and when questioned, the landowner would usually say "It's been there a long time." At Chase No. 1, the rancher remembered the nests as far back as 1908 but in the intervening time the colony has moved a short distance up or down the creek. Chase No. 2 was known to exist in 1927, but about 1949 it disappeared and a new colony was built about 5 km upstream. According to

Table 1. Colony size—growth or decline.

| County | Colony number | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963–72 | 1973 | 1974–77 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Allen | 1 | | | | | | | | | | | | | | | 13 |
| Anderson | 1 | | | | | | | 14 | 29 | 31 | 36 | 37 | | 34 | | 28 |
| | 2 | | | | | | | | 4 | 5 | 5 | 5 | | 0 | | 0 |
| | 3 | | | | | | | | | | | | 14 | 46 | | 17 |
| | 4 | | | | | | | | | | | | | | | 21 |
| Atchison | 1 | | | | | | | | | | | | | 41 | | 12 |
| Barber | 1 | | | | | | | 5 | 5 | 3 | 2 | 1 | | 0 | | 0 |
| | 2 | | | | | | | 5 | 6 | 12 | 21 | 30 | | 66 | | 12 |
| | 3 | | | | | | | | | 14 | 11 | 2 | | 0 | | 0 |
| | 4 | | | | | | | | | | | | 21 | 5 | | 22 |
| | 5 | | | | | | | | | | | | 4 | 0 | | 0 |
| | 6 | | | | | | | | | | | | | | | 14 |
| Barton | 1 | | | | | | | | | | | | | | 32 | 0 |
| | 2 | | | | | | | | | | | | | | | 75 |
| Bourbon | 1 | | | | | | | | | | 28 | 30 | | 75 | | 56 |
| Brown | 1 | | | | | | | | | | 13 | 14 | | 0 | | 0 |
| | 2 | | | | | | | | | | | | | | | 6 |
| Butler | 1 | | | 43 | 33 | 22 | 7 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 2 | | | 11 | 14 | 13 | 16 | 18 | 13 | 20 | 21 | 28 | | 23 | | 11 |
| | 3 | | | | 12 | 18 | 15 | 2 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 4 | | | | 24 | 21 | 17 | 11 | 5 | 0 | 0 | 0 | | 0 | | 0 |
| | 5 | | | | 22 | 19 | 20 | 12 | 21 | 11 | 25 | 8 | | 4 | | 13 |
| | 6 | | | | | 8 | 7 | 8 | 7 | 9 | 16 | 32 | | 71 | | 62 |
| | 7 | | | | | | | 3 | 11 | 2 | 0 | 0 | | 0 | | 0 |
| | 8 | | | | | | | 25 | 31 | 39 | 26 | 28 | | 58 | | 35 |
| | 9 | | | | | | | | | | | | | 22 | | 22 |

Table 1. Continued.

| County | Colony number | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963–72 | 1973 | 1974–77 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chase | 1 | | 51 | 31 | 23 | 14 | 17 | 26 | 28 | 29 | 28 | 24 | | 40 | | 28 |
| | 2 | | 21 | 20 | 20 | 2 | 3 | 5 | 7 | 8 | 16 | 11 | | 27 | | 11 |
| | 3 | | | 12 | 14 | 9 | 9 | 7 | 6 | 2 | 2 | 0 | | 0 | | 0 |
| | 4 | | | 10 | 15 | 8 | 9 | 9 | 10 | 10 | 20 | 20 | | 16 | | 20 |
| | 5 | | | 13 | 15 | 18 | 26 | 19 | 21 | 15 | 13 | 7 | | 0 | | 0 |
| | 6 | | | 13 | 21 | 22 | 25 | 25 | 38 | 35 | 44 | 51 | | 106 | | 80 |
| | 7 | | | 45 | 55 | 50 | 37 | 41 | 26 | 18 | 23 | 28 | | 67 | | 110 |
| | 8 | | | 2 | 9 | 11 | 16 | 24 | 16 | 14 | 23 | 23 | | 36 | | 44 |
| | 9 | | | | | | | 5 | 7 | 6 | 11 | 2 | | 0 | | 0 |
| | 10 | | | | | | | 10 | 11 | 13 | 11 | 8 | | 1 | | 0 |
| | 11 | | | | | | | | | 3 | 6 | 7 | | 0 | | 0 |
| Chautauqua | 1 | | | | 23 | 25 | 25 | 24 | 28 | 30 | 50 | 46 | | 88 | | 51 |
| | 2 | | | | | 12 | 18 | 22 | 17 | 6 | 13 | 18 | | 14 | | 0 |
| | 3 | | | | | | | | 23 | 24 | 10 | 12 | | 13 | | 0 |
| Clark | 1 | | | | | | | | | 21 | 8 | 0 | | 0 | | 0 |
| | 2 | | | | | | | | | | 7 | 3 | | 0 | | 0 |
| | 3 | | | | | | | | | | 16 | 7 | | 0 | | 0 |
| Clay | 1 | | | | | | | | | | | | | | 100 | 75 |
| Cloud | 1 | | 36 | 25 | 20 | 8 | 3 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 2 | | | | | | 8 | 4 | 2 | 2 | 0 | 0 | | 0 | | 0 |
| Coffey | 1 | 16 | 14 | 17 | 20 | 25 | 20 | 12 | 6 | 2 | 3 | 3 | | 0 | | 0 |
| Comanche | 1 | | | | | | | | 4 | 6 | 5 | 4 | | 0 | | 0 |
| | 2 | | | | | | | | | | 45 | 43 | | 57 | | 42 |
| Cowley | 1 | | | | 49 | 48 | 52 | 53 | 54 | 31 | 19 | 35 | | 24 | | 12 |
| | 2 | | | | 103 | 87 | 93 | 55 | 66 | 42 | 45 | 50 | | 58 | | 16 |
| | 3 | | | | 25 | 23 | 14 | 5 | 2 | 0 | 0 | 0 | | 10 | | 0 |
| | 4 | | | | 7 | 7 | 38 | 31 | 21 | 22 | 26 | 31 | | 31 | | 12 |

Table 1. Continued.

| County | Colony number | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963–72 | 1973 | 1974–77 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Crawford | 1 | | | | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 2 | | | | | | | | | | | | | | | 3 |
| Dickinson | 1 | 119 | 119 | 135 | 154 | 105 | 98 | 98 | 104 | 94 | 63 | 73 | | 64 | | 54 |
| | 2 | | | | | | 26 | 8 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| Doniphan | 1 | | | | | | | | 36 | 37 | 39 | 28 | | 27 | | 30 |
| Douglas | 1 | | | | | | 55 | 53 | 41 | 48 | 33 | 21 | | 37 | | 28 |
| | 2 | | | | | | | 10 | 11 | 8 | 3 | 2 | | 0 | | 0 |
| | 3 | | | | | | | | | | | | 8 | 0 | | 0 |
| Elk | 1 | | | | 14 | 5 | 8 | 4 | 8 | 14 | 9 | 5 | | 0 | | 0 |
| | 2 | | | | | | | 2 | 1 | 0 | 0 | 0 | | 0 | | 0 |
| | 3 | | | | | | | | | | 21 | 19 | | 13 | | 9 |
| | 4 | | | | | | | | | | 7 | 7 | | 28 | | 17 |
| | 5 | | | | | | | | | | | | | | | 15 |
| Ellis | 1 | | | | 10 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 2 | | | | | | | 2 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 3 | | | | | | | | | 8 | 4 | 3 | | 0 | | 0 |
| | 4 | | | | | | | | | | | | | 12 | | 1 |
| | 5 | | | | | | | | | | | | | 5 | | 0 |
| | 6 | | | | | | | | | | | | | 15 | | 4 |
| Ellsworth | 1 | | 15 | 15 | 18 | 32 | 45 | 53 | 83 | 67 | 38 | 10 | | 0 | | 0 |
| Finney | 1 | | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 2 | | 21 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 3 | | 4 | 10 | 15 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 4 | | | | | | | 4 | 4 | 0 | 0 | 0 | | 0 | | 6 |
| Ford | 1 | | | | | 15 | 11 | 5 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 2 | | | | | | 7 | 6 | 8 | 7 | 6 | 0 | | 0 | | 0 |

Table 1. Continued.

| County | Colony number | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963–72 | 1973 | 1974–77 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Franklin | 1 | | | | | | 4 | 4 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 2 | | | | | | | | 11 | 8 | 7 | 8 | | 46 | | 30 |
| | 3 | | | | | | | | | | | 8 | | 0 | | 12 |
| | 4 | | | | | | | | | | | | | | | 8 |
| Geary | 1 | | | | | | | | | | | | | 149 | | 146 |
| Gove | 1 | | | | | 4 | 7 | 7 | 17 | 10 | 6 | 2 | | 0 | | 0 |
| | 2 | | | | | 5 | 4 | 3 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| | 3 | | | | | | | | | | | 18 | | 4 | | 12 |
| Graham | 1 | | | | | | | 5 | 6 | 4 | 4 | 14 | | 0 | | 2 |
| Grant | 1 | | | | | | | | | | 8 | 6 | | 0 | | 0 |
| Greenwood | 1 | 33 | 33 | 44 | 38 | 40 | 43 | 35 | 11 | 6 | 9 | 5 | | 0 | | 0 |
| | 2 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | 6 | 10 | 7 | 4 | | 0 | | 4 |
| | 3 | | | | | | 8 | 8 | 4 | 8 | 12 | 17 | | 0 | | 0 |
| | 4 | | | | | | | 19 | 18 | 25 | 11 | 24 | | 20 | | 22 |
| | 5 | | | | | | | 36 | 39 | 35 | 35 | 24 | | 0 | | 0 |
| | 6 | | | | | | | | 8 | 12 | 13 | 15 | | 0 | | 0 |
| Hodgeman | 1 | | | | | 11 | 18 | 4 | 8 | 3 | 1 | 2 | | 11 | | 21 |
| | 2 | | | | | 11 | 6 | 1 | 1 | 0 | 0 | 0 | | 0 | | 0 |
| | 3 | | | | | | | 7 | 6 | 5 | 8 | 4 | | 0 | | 0 |
| Jefferson | 1 | | | | | | | 31 | 35 | 27 | 34 | 24 | | 0 | | 0 |
| | 2 | | | | | | | | | | | | | | | 92 |
| Johnson | 1 | | | | | | | | | | | | 34 | 14 | | 20 |
| Kearny | 1 | | | 18 | 18 | 16 | 11 | 8 | 14 | 10 | 14 | 18 | | 21 | | 20 |
| Kingman | 1 | | | | | | | 4 | 9 | 9 | 13 | 12 | | 94 | | 48 |
| Kiowa | 1 | | | | | | 18 | 20 | 23 | 15 | 5 | 2 | | 0 | | 0 |

Table 1. Continued.

| County | Colony number | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963–72 | 1973 | 1974–77 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Labette | 1 | | | | | | | 22 | 35 | 37 | 14 | 4 | | 0 | | 0 |
| | 2 | | | | | | | | | | | | | 24 | | 65 |
| Lane | 1 | | | | | | 12 | 13 | 18 | 6 | 11 | 6 | | 54 | | 0 |
| | 2 | | | | | | | 31 | 33 | 22 | 26 | 24 | | 2 | | 8 |
| Leavenworth | 1 | | | | | | | | | | | | | 55 | | 81 |
| | 2 | | | | | | | | | | | | | 41 | | 9 |
| Linn | 1 | | | | | 29 | 40 | 33 | 41 | 63 | 86 | 89 | | 116 | | 116 |
| | 2 | | | | | | | | | | | | | | | 92 |
| Logan | 1 | | | | | | | 34 | 30 | 40 | 43 | 43 | | 27 | | 13 |
| Lyon | 1 | | 4 | 10 | 18 | 21 | 18 | 6 | 4 | 2 | 0 | 0 | | 0 | | 0 |
| | 2 | | | 15 | 11 | 0 | 3 | 6 | 3 | 6 | 10 | 14 | | 0 | | 40 |
| | 3 | | | 27 | 30 | 18 | 19 | 36 | 35 | 33 | 41 | 35 | | 3 | | 0 |
| | 4 | | | | 15 | 12 | 9 | 14 | 15 | 12 | 12 | 3 | | 108 | | 88 |
| | 5 | 11 | 11 | 16 | 23 | 26 | 25 | 22 | 23 | 29 | 31 | 36 | | 0 | | 0 |
| | 6 | | | | | | | 26 | 26 | 23 | 19 | 3 | | 0 | | 0 |
| | 7 | | | | | | | | | | | | | | | 5 |
| Marion | 1 | | | | | 7 | 22 | 20 | 18 | 15 | 24 | 23 | | 4 | | 0 |
| Marshall | 1 | | | | | | | | 15 | 12 | 16 | 9 | | 0 | | 0 |
| McPherson | 1 | | | | 9 | 4 | 2 | 2 | 4 | 6 | 4 | 0 | | 0 | | 0 |
| | 2 | | | | | | | 10 | 10 | 8 | 7 | 2 | | 0 | | 0 |
| | 3 | | | | | | | | | 14 | 17 | 26 | | 15 | | 4 |
| Meade | 1 | | | | | | | | 25 | 38 | 35 | 33 | | 3 | | 0 |
| | 2 | | | | | | | | | | 6 | 0 | | 0 | | 0 |
| Miami | 1 | | | | | | | | 16 | 29 | 37 | 37 | | 26 | | 32 |
| Mitchell | 1 | | | | | | | | | | | | | | ? | 0 |

Table 1. Continued.

| County | Colony number | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963–72 | 1973 | 1974–77 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Montgomery | 1 | | | 2 | 2 | 2 | 3 | 5 | 12 | 15 | 17 | 28 | | 88 | | 87 |
| | 2 | | | | 45 | 42 | 43 | 48 | 55 | 20 | 20 | 18 | | 42 | | 0 |
| | 3 | | | | | | | | | | | | | 15 | | 9 |
| Morris | 1 | | | | | 29 | 30 | 28 | 37 | 39 | 37 | 32 | | 0 | | 0 |
| | 2 | | | | | | | | 18 | 18 | 28 | 37 | | 10 | | 40 |
| | 3 | | | | | | | | | | | | | | | 48 |
| Nemaha | 1 | | | | | | 10 | 9 | 22 | 15 | 22 | 29 | | 0 | | 3 |
| Neosho | 1 | | | | | | | | | | | | | | | 16 |
| Norton | 1 | | | | | | | | | | | | | | 15 | 0 |
| Osage | 1 | 47 | 55 | 34 | 11 | 14 | 18 | 13 | 2 | 0 | 0 | 0 | | 0 | | 0 |
| | 2 | | 23 | 18 | 21 | 15 | 15 | 16 | 8 | 5 | 4 | 2 | | 33 | | 5 |
| | 3 | | | | | | | | 14 | 19 | 13 | 25 | | 21 | | 0 |
| | 4 | | | | | | | | | 18 | 11 | 6 | | 20 | | 13 |
| | 5 | | | | | | | | | | | | | 15 | | 0 |
| Osborne | 1 | | | | | | | | | | | | | | | 38 |
| Ottawa | 1 | | | | | 6 | 8 | 11 | 14 | 10 | 4 | 0 | | 0 | | 0 |
| | 2 | | | | | | | | | | 9 | 4 | | 0 | | 0 |
| | 3 | | | | | | | | | | | | | | 20 | 0 |
| Phillips | 1 | | | | | | | | | | | | | | | 19 |
| Pottawatomie | 1 | 65 | 66 | 51 | 33 | 13 | 9 | 4 | 20 | 23 | 23 | 20 | | 36 | | 19 |
| | 2 | 70 | 56 | 52 | 43 | 41 | 29 | 24 | 20 | 35 | 34 | 40 | | 92 | | 46 |
| | 3 | 15 | 15 | 13 | 10 | 10 | 5 | 11 | 10 | 13 | 16 | 22 | | 23 | | 12 |
| | 4 | | 3 | 3 | 2 | 0 | 8 | 5 | 2 | 6 | 5 | 2 | | 0 | | 0 |
| | 5 | | | | | | | | | | | | | | 10 | 15 |
| Rawlins | 1 | | | | | | | | | | | | | | 42 | 22 |
| | 2 | | | | | | | | | | | | | | 3 | 0 |

Table 1. Continued.

| County | Colony number | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963–72 | 1973 | 1974–77 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Republic | 1 | | | 8 | 12 | 29 | 27 | 9 | 0 | 0 | 0 | 0 | | 0 | | 0 |
| Rice | 1 | | | | | | | 3 | 2 | 0 | 0 | 0 | | 0 | | 0 |
| Riley | 1 | 36 | 32 | 43 | 42 | 25 | 32 | 22 | 20 | 20 | 23 | 27 | | 0 | | 0 |
| | 2 | | 9 | 4 | 6 | 3 | 7 | 3 | 1 | 0 | 0 | 4 | | 58 | | 73 |
| | 3 | | 32 | 37 | 37 | 24 | 23 | 29 | 29 | 29 | 18 | 18 | | 47 | | 3 |
| | 4 | | 42 | 30 | 42 | 36 | 34 | 34 | 18 | 19 | 25 | 8 | | 0 | | 0 |
| | 5 | | | 21 | 24 | 19 | 3 | 3 | 7 | 3 | 6 | 8 | | 26 | | 51 |
| Rooks | 1 | | | | | | | | | 15 | 2 | 0 | | 0 | | 2 |
| Russell | 1 | | | | | | | | | 5 | 5 | 3 | | 0 | | 0 |
| | 2 | | | | | | | | | | | | | | | 58 |
| Scott | 1 | | | | | | | | 6 | 7 | 7 | 5 | | 0 | | 0 |
| Sedgwick | 1 | | 187 | 215 | 210 | 187 | 190 | 187 | 197 | 158 | 158 | 155 | | 235 | | 198 |
| Seward | 1 | | | | | | | | | | 15 | 14 | 18 | 0 | | 0 |
| | 2 | | | | | | | | | 7 | 14 | 8 | 5 | 0 | | 0 |
| Sheridan | 1 | | | | | | | | | | 19 | 19 | | 3 | | 2 |
| | 2 | | | | | | | | | | | | | | 7 | 0 |
| Sherman | 1 | | | | | | | | | | | | | 5 | | 1 |
| Stafford | 1 | | | | | | | | | | | 45 | 40 | 0 | | 0 |
| Sumner | 1 | | | | | 14 | 11 | 6 | 1 | 1 | 8 | 3 | | 0 | | 0 |
| | 2 | | | | | | | 14 | 19 | 5 | 3 | 1 | | 0 | | 0 |
| | 3 | | | | | | | | | 71 | 48 | 15 | | 0 | | 0 |
| | 4 | | | | | | | | | | 2 | 4 | | 0 | | 0 |

Table 1. Continued.

| County | Colony number | 1952 | 1953 | 1954 | 1955 | 1956 | 1957 | 1958 | 1959 | 1960 | 1961 | 1962 | 1963–72 | 1973 | 1974–77 | 1978 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trego | 1 | | | | | | | | | | | | | | | 10 |
| | 2 | | | | | | | | | | | | | | | 12 |
| Wabaunsee | 1 | 53 | 55 | 52 | 47 | 31 | 10 | 3 | 6 | 3 | 0 | 0 | | 0 | | 0 |
| | 2 | 30 | 30 | 35 | 59 | 49 | 51 | 40 | 43 | 37 | 46 | 29 | | 0 | | 0 |
| | 3 | | | 23 | 19 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | | 37 |
| | 4 | | | | | | 9 | 16 | 19 | 11 | 13 | 10 | | 0 | | 0 |
| | 5 | | | | | | | 66 | 89 | 95 | 87 | 84 | | 71 | | 42 |
| Wallace | 1 | | 13 | 12 | 9 | 7 | 7 | 4 | 3 | 2 | 0 | 0 | | 0 | | 0 |
| | 2 | | | | | 14 | 15 | 29 | 23 | 26 | 28 | 23 | | 0 | | 0 |
| | 3 | | | | | | | | | | | | | | 7 | 3 |
| Washington | 1 | | 49 | 31 | 33 | 17 | 25 | 19 | 10 | 26 | 23 | 16 | | 18 | | 25 |
| Wilson | 1 | | | | | | | 9 | 11 | 11 | 19 | 14 | | 0 | | 0 |
| | 2 | | | | | | | | | | 33 | 41 | | 30 | | 38 |
| Woodson | 1 | 19 | 21 | 24 | 32 | 32 | 41 | 36 | 47 | 52 | 41 | 54 | | 50 | | 51 |
| Total nests | | 519 | 1023 | 1247 | 1638 | 1510 | 1677 | 1898 | 2180 | 2211 | 2376 | 2284 | | 3009 | | 3075 |
| Total active colonies | | 13 | 29 | 43 | 55 | 66 | 74 | 98 | 105 | 107 | 115 | 112 | | 76 | | 94 |
| Average nests per colony | | 39.92 | 35.27 | 29.00 | 29.78 | 22.87 | 22.66 | 19.36 | 20.76 | 20.66 | 20.66 | 20.39 | | 39.59 | | 32.71 |

Table 2. Distribution and size of heron colonies in eastern and western counties, 1962, 1973, 1978.

| Year | Area | Number of counties | Active colonies | Total nests | Average nests per colony | Percent of total nests |
|---|---|---|---|---|---|---|
| 1962 | East | 31 | 75 | 1669 | 22.25 | 73.07 |
| | West | 24 | 37 | 615 | 16.62 | 26.93 |
| 1973 | East | 30 | 58 | 2375 | 40.95 | 78.93 |
| | West | 13 | 18 | 634 | 35.22 | 21.07 |
| 1978 | East | 36 | 67 | 2406 | 35.91 | 78.24 |
| | West | 23 | 27 | 669 | 24.77 | 21.71 |

the records of John Breukelman, Emporia State University, Chase No. 7 has been in the same location since 1937; Dickinson No. 1 had 75 nests in 1933; and Lyon No. 1 moved a great deal between 1927 and 1961, then disappeared. Barber No. 3 was in the same location in the 1920's, but about 1960 the large cottonwood nesting trees started to die and were gone in 1963.

At Butler No. 1 some of the nesting trees and surrounding trees were cut in 1955 with a corresponding decrease in the number of nests and no nests were left in 1958. During the study several colonies moved around within a radius of 3 km for no known reason; some disappeared entirely so that of the 13 known colonies in 1952, 6 remained active in 1978; of the 29 known in 1953, only 13 were still active in 1978; and of the 191 sites known to have been used, only 94 were active in 1978, these with a total of 3075 nests.

## Selection of a Nest Site

Three factors are usually given as necessary for the establishment of a nesting site: 1) presence of suitable trees; 2) remoteness; 3) available food supply. In 24 counties we have found no colonies even though these conditions are present, a few of these counties can be eliminated because of

Table 3. Distribution and size of heron colonies in Kansas and Arkansas river drainage areas, 1962, 1973, 1978.

| Year | Area | Number of counties | Active colonies | Total nests | Average nests per colony | Percent of total nests |
|---|---|---|---|---|---|---|
| 1962 | Kansas | 27 | 44 | 916 | 20.82 | 40.10 |
| | Arkansas | 29 | 68 | 1368 | 20.12 | 59.90 |
| 1973 | Kansas | 22 | 34 | 1305 | 38.38 | 43.37 |
| | Arkansas | 22 | 42 | 1704 | 40.57 | 56.63 |
| 1978 | Kansas | 33 | 49 | 1508 | 30.78 | 49.04 |
| | Arkansas | 24 | 45 | 1567 | 34.82 | 50.96 |

Table 4. Number of trees used with number of nests in east and west areas, 1978.

| | Sycamore | | Cottonwood | | Other trees | | Total | |
|---|---|---|---|---|---|---|---|---|
| | East | West | East | West | East | West | East | West |
| Number of trees | 366 | 0 | 21 | 214 | 11 | 16 | 399 | 231 |
| Number of nests | 2312 | 0 | 79 | 633 | 15 | 36 | 2406 | 669 |
| Percent of total nests | 75.19 | 0 | 2.57 | 20.59 | 0.49 | 1.17 | | |
| Average nests per tree | 6.30 | 0 | 3.76 | 2.94 | 1.36 | 2.25 | | |

the presence of large cities or military bases. The eastern row of counties is rather densely wooded but there are few colonies there, perhaps because there are insufficient trees which stand out above the others (table 4).

It is possible that the large size of the heron plays an important part in the choice of a nesting site. The nearly 2 m wingspread would cause difficulty when the heron comes down through dense woods, so most of the nests are placed in the uppermost branches of the tree. Both the cottonwood and sycamore have coarse upper branches which give openness to the tree top, but sycamore branches are much stronger than those of cottonwood. Obviously the fine branches of an elm cannot be used successfully to hold a heavy nest. When herons are frightened from their nests they take off quickly and fly directly to an open, cultivated field or a prairie hillside and remain standing there. After a time a few of them fly back and circle the nesting tree and if the intruder is gone, the other herons return. It is not known whether the birds merely utilize these open areas or if they select the site because of them, but this combination of trees and open areas is typical of the Flint Hills region where almost half of the colonies are situated.

A good stream flow and a high water table for maintaining springs and farm ponds is important to the heron food supply and it may seem odd that the majority of the colonies are not along the larger streams but are on the small, often intermittent, streams in the upper reaches of the watershed. This may give the herons a sense of security because the site is more remote from human activities. In 1978 only 3 active colonies were known along the Arkansas River even though it is bordered by large cottonwoods throughout its course in the state. The only colony directly on a major stream of the Kansas River system was in the dead trees of Milford Lake—a secure place.

There is evidence that the creation of large reservoirs has affected the location and size of colonies. In eastern Lyon County, two colonies apparently merged when the location of one of them was destroyed for the construction of John Redmon Dam. The colony on the Republican River at the upper end of Milford Lake became large when the water flooded the trees and killed them. The heron feeds in shallow water and will continue to feed in small streams and ponds rather than along the steep shores of large lakes.

Fig. 2. Adult Great Blue Heron—a mounted specimen in a natural setting.

## Size of Colony

The number of nests in a colony may vary greatly from year to year (Table 1), possibly because of variation in annual rainfall which affects the food supply. 1951 was an extremely wet year throughout the state but it was followed by a dry period for 5 years and during this period the average size of the colonies dropped from 39.92 to 22.87 nests. The next 8 years were of average rainfall but because many of the rains were local, there were wet areas and dry areas, but the average colony size for the state remained fairly constant. This situation was probably the cause of the concentration of the nests into fewer but larger colonies so that in 1973 there were only 76 active colonies but these had an average of 39.59 nests each.

There is no way of knowing how many of the 1973 colonies actually existed prior to 1952 so there can be no long range comparison of their size, but in 1953 there were 1023 nests in 29 colonies, an average of 35.27 nests; in 1962, 21 of these colonies remained with a total of 563 nests, an average of 26.80 nests per colony—a dramatic reduction of colony size in the 10 year period. In 1973 only 12 of the 29 colonies remained active, but these had 723 nests, an average of 60.25 nests per colony. This clearly indicates a concentration of the herons. However, because one colony was rejuvenated, 13 of the colonies were active in 1978, these with a total of 529 nests, an average of 40.69 nests per colony. This would mean that the herons were spreading out again.

## Associations

Besides the effects of variation in annual rainfall other birds and mammals may affect both the location and the size of a colony. Birds of prey are the most common species to share the nesting areas with the herons, but even though a red-tailed hawk or great horned owl may nest in the same tree with the herons, we have not observed predatory actions. In some colonies where a predator nests in the same tree with herons, the herons leave temporarily when the predator flies to its nest but the herons seldom leave when the predator takes off. More often, as the predator flies to its nest, the herons will merely rise to a squatting position and face the incoming bird. In one colony a red-tailed hawk nested in the same tree with the herons during 5 successive years with no obvious effect on the colony size.

The bald and golden eagles are common winter residents in western Kansas and often use a heron colony for roosting. In 7 different colonies the eagles built winter nests within the colony but did not lay eggs. In Lane No. 1 the eagles built on top of a heron nest and the following summer the herons used that nest. This alternation of the use of a nest continued 4 years. Five other colonies were used by eagles but they did not build nests even though they did add a stick or two to a heron nest. Since the eagles are usually

Fig. 3. Typical colony in winter.

gone before the herons arrive in the spring and do not return until the herons have left in the fall, there is little chance of harassment to the herons.

The turkey vulture is not a predator, but is commonly associated with heron nesting sites. At 5 colonies, vultures have used the immediate area for roosting, at times as many as 25 vultures each night and this may irritate the herons. During the period when the young herons are in the nest, vultures commonly sail overhead, perhaps the odor from the heron nest attracts them, or they may be looking for a young bird that has fallen from the nest.

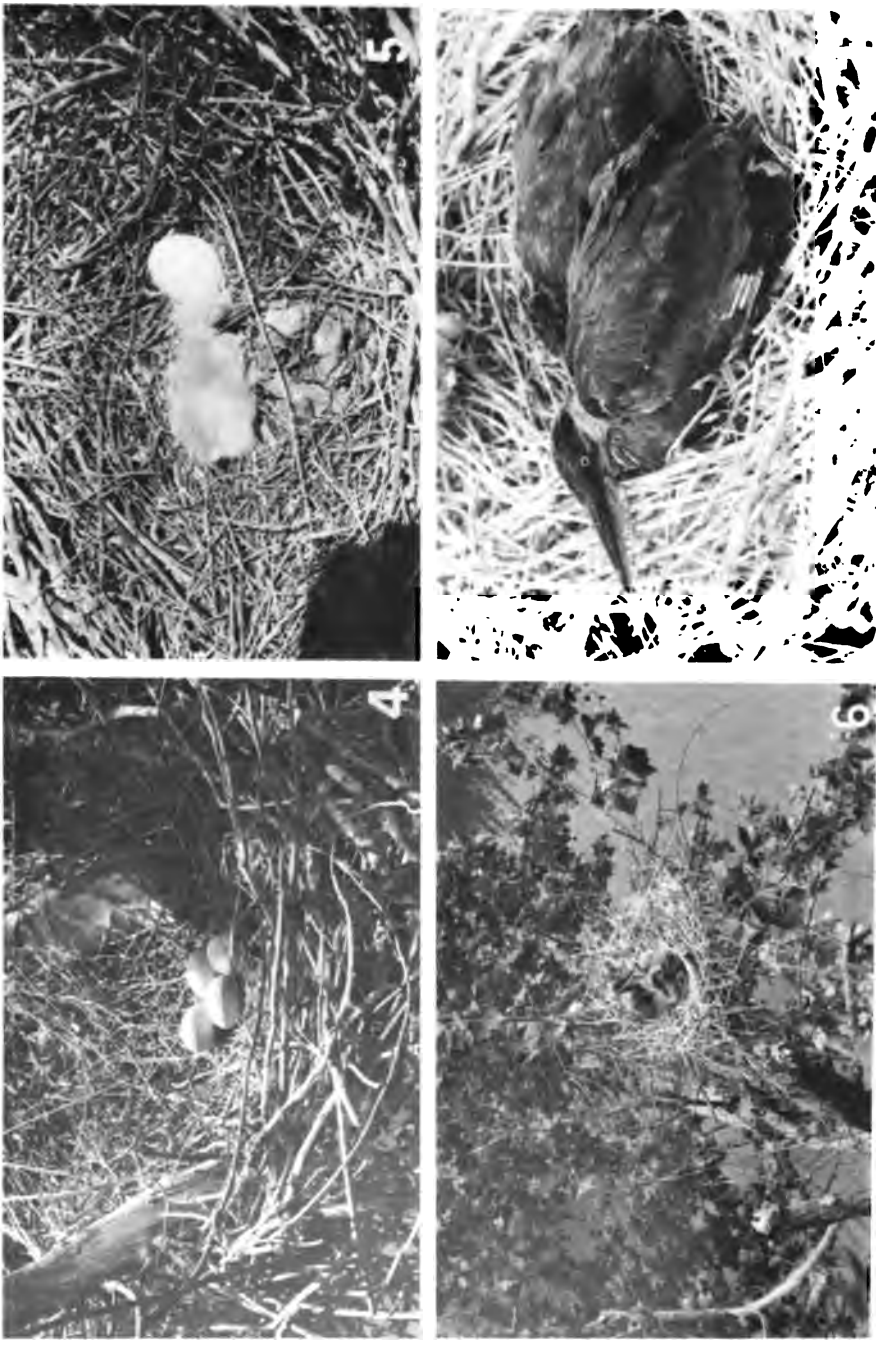
English sparrows and starlings often raise young in the base of a heron nest and the northern oriole sometimes hangs its nest on a nearby limb. In one case a crow nested in a lower tree at the edge of the colony and each year 2 or 3 pairs of great egrets nest in the same trees with the great blue herons at Cowley No. 4. When Meade No. 1 was counted in 1961 there were 16 smaller nests, low in the trees and on smaller limbs than could have been used by the great blue herons. Since the site had not been visited that summer, it was assumed these nests were those of black-crowned night herons.

The following list is given to summarize the number of colonies in or near which another species has been known to nest or roost: red-tailed hawk, 37; great horned owl, 15; barred owl, 3; Swainson's hawk, 1; crow, 1; red-tailed hawk and barred owl, 1; great egret, 1; black-crowned night heron, 1; eagle roosts, 12; vulture roosts, 5.

Among mammals, man is definitely the worst enemy of the heron, primarily from cutting the nesting trees. Some landowners attempt to discourage the birds, even by shooting, because the herons "eat the fish from the ponds and streams, are dirty and carry disease, and the young are noisy day and night." At 8 of the colonies a farmer put his feedlot in the grove of nesting trees to take advantage of summer shade and winter wind protection. The landowner at Sedgwick No. 1 said that an airplane once made several low flights over the colony and the occupants shot the herons. This was verified during the winter count when the remains of several adult birds were seen on the ground. Herons are sometimes used as targets; in one colony, two adult birds were seen hanging over the edge of their nests.

Other ways in which man interferes with the herons is under the guise of research, or from idle curiosity. One colony, situated near a high bluff attracts groups of people who drive near to the nests and on about the same level. This colony has diminished to about half its original size. Occasionally someone builds a blind within the colony, which may not bother the birds, but the movements and noises scare the herons from their nests. In a Wabaunsee colony a blind was not built, but cleats were nailed to the tree so a person could go up and down easily.

Although the collection of data was officially closed in 1979—after the



Figs. 4–7. 4. Nest and eggs. 5. Young heron 2 days old. 6. Young herons about 3 weeks old. 7. Young herons about 5 weeks old.

1978 winter count of nests—there cannot be a true completion of nesting data because new colonies are being found or formed each year and other colonies may disappear. However, new data will be filed for possible future publication.

## Life and Habits of the Great Blue Heron

Much has been written concerning the life history of the Great Blue Heron but the data most often have been gathered from blinds below nest level or from only a few nests. To better observe the activities of the herons, in 1962 Jack Knouse, a graduate student at Emporia State University, constructed a tower 20 m high next to Lyon No. 6. This put him on a level with 11 nests and beginning on March 10 he was in the blind every morning before sunrise for a period of 6 weeks, then for another 6 weeks he visited the colony two or three times a week. In 1963, at Wabaunsee No. 5, I set up a blind 5 m high on a wooded bluff 28 m high located so I could see over the trees on the bluff and down into 45 nests in 2 trees. The remainder of this report is a combination of our observations.

### Arrival

The great blue herons do not all arrive at a colony on the same day in the spring because they do not migrate in flocks, also a few birds may remain in Kansas over winter. Occasionally in January or February a heron may be seen feeding when snow covers the ground and, except for riffles, streams and ponds are frozen. Beginning about the first week of March the herons start arriving and interested landowners call these birds the "Scouts." One of these men stated "These birds seem to be investigating because they are restless. They land in the trees or out in the field and just walk around and they are easily alarmed. Sometimes they fly in a circle perhaps a quarter of a mile across before coming in and landing again." By March 15 most of the herons have arrived, but late arrivals continue to join the group, build nests and raise young. May 20 is our latest record of a new nest; this may have been a late arriving pair or a pair which renested as a few days before this date a wind storm destroyed two nests with young. In this late nest, the first egg hatched at the time the young of other nests were fledging.

### Courtship

By the end of the fourth day after arrival the territories have been selected. On March 11 Knouse observed the first sign of territorial defense. In some cases a lone bird will defend an area, but usually there are two and during this early defense period the two birds stand on or near a nest and show no sign of a desire to build. For the first day neither bird pays any special attention to the other, but on the second day they preen each other

or occasionally one may snap at the other's bill. Often one bird may sit on the nest and while the other stands close by, will stretch its neck straight out and down over the side of the nest and clack the bill. At times both birds sit on the nest and extend their necks out, down and crossed, or they may stand in the nest facing each other with their necks up and crossed. These actions are accompanied by a soft "oo-oo-oo" or a gurgling sound and takes place about 2 days before copulation. Often the birds will jab at each other's bill and eventually lock their bills together and move their necks back and forth in a see-saw fashion. This same action was observed with the birds holding opposite ends of a stick as if trying to take it away from the other. This stick may be one that has just been brought to the nest or it may have been picked off of the edge of the present nest. On occasions a bird may shake its head sidewise vigorously, or pick up a stick and shake it. During all these courtship activities the crest is erect and the neck plumes are extended.

One of the most striking actions and sounds associated with courtship has been termed "howling." Knouse called it "bitterning" because the bird's posture is similar to the freeze stance of the bittern. In this display, the bird of either sex starts from a half-standing position, raises the neck vertically with the bill forming a straight line with the neck. Then as the bird rises to a full standing position it emits a sound which reminds me of the howl of a coyote. The sound becomes louder and of higher pitch as the bird rises, then softer and with lower pitch as the bird settles back to a squatting position. Just before it sits, the body sways from side to side or moves in a circular motion. Both birds of a known pair have been observed to go through this display. It is often performed by the brooding bird when its mate brings a stick to the nest, but before the stick is accepted. As in many birds, these courtship displays continue into and after the brooding season.

There are many other sounds which come from a colony at this season but the most common are the harsh, sharp squawks of warning or fighting, for struggles are common. If an incoming bird gets too close to another nest, there will be a noisy warning to move on. This is usually a short, sharp "bark," but it may be drawn out at the end.

Usually the herons pair off within a few days after arrival, but after most of the nests had eggs in them, one bird, presumed to be the same bird each day, spent most of 3 days standing alone on a low, dead limb fully 6 m from any nest, not permitting another bird to come near. During these 3 days it howled often, so often that I timed it at 3 howls in 5 minutes. By the morning of the fourth day a mate had been accepted and a nest was started, the courtship being extremely short.

## Nest Building

The typical nest of the great blue heron is a structure of coarse branches lined with finer twigs or weeds. It is about 1 m in diameter and 10 to 30 cm

deep. At the beginning, the depth of the bowl is shallow but as new material is added throughout the season, the depth increases. Nests are used year after year, or they may be destroyed entirely after the first year. I have no information as to whether or not either member of a pair comes back to the same nest the following year. Since the nests are used over and over and new material added each year, one would think that eventually they would become quite large. But this is not true because winter storms take a toll of the nests or break them apart sufficiently so they must be rebuilt. Also, herons may steal sticks from any nest, occupied or not.

A new nest is often rather flimsy, so thin that I have counted the number of eggs by standing on the ground directly beneath, but these nests are sturdily built by fall. The nests are placed as far toward the top of the tree or the end of a branch as the strength of the limb will permit, but a few nests are placed on limbs over 18 cm diameter. This is especially true when the tree leans out over water.

Nest building usually starts about March 15 and the material is gathered from 3 general sources: the ground, a dead tree, or another nest. It is seldom that a heron will get nest material from directly under the nest tree, but may land in the open, usually more than 90 m from the nest, and walk into the woods for material. This is a bit strange because at Wabaunsee No. 5, the birds repeatedly flew across the creek and broke branches from a dead tree less than 15 m from their nest. A bird may wrestle with a branch it cannot break then leave it and find a weaker one. Downstream about 100 m from the main nest tree in Wabaunsee No. 5 were 3 old nests but within a week all 3 were removed. One heron in this colony discovered an old nest which had fallen and lodged against the tree trunk about 10 m from the ground. The bird flew directly down through the tree, removed a branch from the nest and flew horizontally from the tree and made a wide circle upward to its own nest.

When a male carrying a stick arrives at the nest, the female usually rises, with or without other forms of greeting, takes the stick and places it in the nest while he preens her feathers or stands on a limb and preens himself. On several occasions (different birds) the female paid no attention when the male came in with a stick. Finally, the stick was dropped on top of the sitting female, which then turned, took the stick and placed it in the nest.

By April 16 the females seem much less interested in new nest material and on one occasion the male brought a stick about 2 m long but the female refused it. He flew holding one end of the stick while the other end hung backward at an angle of about 45° and instead of trying to put it in the nest, he balanced it across a horizontal limb. Then something alarmed the birds and the stick fell to the ground. The birds do not go down and retrieve a stick which has dropped but will leave and get another.

When the male is coming in with nest material he may squawk when about 15 m from the nest and the female turns her head and may rise to her

Table 5. Size of clutch.

| Year | Colony | Number of nests | Number of eggs | Average number of eggs per nest |
|---|---|---|---|---|
| 1960 (Knouse) | Doniphan No. 1 | 17 | 59 | 3.47 |
| | Douglas No. 2 | 8 | 38 | 4.75 |
| 1961 (Knouse) | Douglas No. 1 | 9 | 33 | 3.67 |
| 1962 (Knouse and Stephens) | Wabaunsee No. 5 | 25 | 79 | 3.16 |
| | Cowley No. 2 | 50 | 198 | 3.96 |
| | Cowley No. 4 | 9 | 29 | 3.22 |
| 1963 (Stephens) | Wabaunsee No. 5 | 42 | 164 | 3.90 |

feet as he lands. The action of the female varies greatly from totally ignoring the mate to raising the crest, standing, facing the male and going through the howling routine.

When a heron comes in for a landing, with or without nesting material, it extends the neck when about 15 m from the nest and at about 9 m the legs are lowered, usually with the feet far apart. On take-off, the neck is extended immediately, even before the bird leaves the perch but is folded back by the time the bird is 7 m away. The feet are extended to the rear but are held well apart until the neck is folded back. If the bird leaves the nest to land on the ground nearby, the neck may not be curved back at all.

## Copulation

There is a great deal of "rape" among the herons. In one instance, a male left the nest where he was sitting on eggs, flew down to a female sitting on an empty nest and copulated with her—much against her will. She resisted and squawked and as he stepped from her back to the edge of the nest, she took a bill full of feathers from his body. He left with much squawking and returned to sit on his own nest. Another time a male was copulating with a female when another male came in quickly, drove him away and started copulation. A third bird came in and drove the second one away but did not copulate. Instead, he flew to a limb about 3 m away and just stood there.

## Egg Laying

In Wabaunsee No. 5 the first egg was layed on March 22 and egg laying reached its peak April 5. The latest date observed for egg laying was May 25 in a nest that was built late and these eggs are known to have hatched but because of a lack of visits I can only presume that the young fledged. Most of the eggs are layed in the morning while the female is incubating the previously layed eggs.

The size of the clutch varies from 3 to 6 eggs (Table 5). These counts

were made about the third week of incubation and when Knouse and I visited the two Cowley County colonies 10 days later, we found 32 young in Cowley No. 2 and none in Cowley No. 4. An egg count was also made and all previous eggs were accounted for. One pair of herons in Wabaunsee No. 5 selected an old nest, rebuilt it and the first egg was layed on March 25. The eggs were apparently not fertile because 3 months later, June 23, the pair was still incubating the 4 eggs.

## INCUBATION

Until the clutch is completed one of the pair stays at the nest most of the time either sitting on the eggs or standing on the edge of the nest, but when all eggs are laid, incubation is nearly continuous. When the nest is built late and the eggs are laid later in the season, the bird does not sit on them as continuously as do the earlier incubating birds. The higher air temperature and the greater amount of direct sunlight may make constant incubation unnecessary.

Both birds take part in incubation and the eggs are seldom left exposed for any length of time; on cold and rainy days some of the birds did not leave the nest when I entered the blind in mid-morning. The birds which did leave returned within a few minutes, whereas before incubation started they were gone for 20 or 30 minutes. At an exchange of birds on the nest, the new bird usually lands on a limb and walks to the nest, the brooding bird rises, steps from the center of the nest and preens itself for a while, or she may fly away immediately. The new bird stands on the nest for a while, turns the eggs with either the feet or the bill, then settles down to continue the incubation. On one occasion such an exchange was made with a greeting at a nest containing no eggs. On another occasion while the incubating birds were still gone after being alarmed, one bird came in with a stick and not finding its mate, placed the stick in the nest, "billed" the eggs and sat on them.

Some birds turn the eggs often, every half hour, while others were not seen to move the eggs except during the exchange of birds on the nest. Usually just before the bird rises to turn the eggs it will reach out and rearrange nest material, then rise and turn part way around in the nest, bill the eggs, rearrange more twigs and sit down. The whole process takes about 3 minutes.

The eggs hatch after 4 weeks of incubation and as might be expected, they do not all hatch on the same day. The young have dark skin covered with a dusky, yellow-gray down which is much longer on the top of the head than on other parts of the body. The bill is dark, but not black, and the head and bill are disproportionately large. Perhaps these heavy heads may explain why the very young spend much of their time lying on their stomachs with the head and neck stretched out flat on the nest.

## FEEDING

No young birds were observed to have received food on the first day but food was brought to them on the second day. Between feedings one adult sits on the nest to keep the chicks warm and to continue the incubation of the remaining eggs.

The adult does not put the food into the bill of the young but regurgitates it into the nest and the young pick it up. The adult places the tip of the bill against the bottom of the nest and may stand in this position for as much as 60 seconds, then the neck begins to pulsate, the throat extends and the food is regurgitated. If any of it is too large for the young, the adult swallows it again. By the time the young are a week old they start picking at the adult's closed bill when it is put into the nest. As the young mature, the adult holds the bill high in the air in a definite attempt to keep the young from touching it until the adult is ready to regurgitate.

When the young are 3 or 4 days old they start making a soft "cha-cha" sound, especially when the adult comes in with food. Bu the time they reach the early pin feather stage, about 15 days, this sound changes to a harsh "yak-yak" which becomes quite loud as the adult approaches. By then they are large enough to grasp the adult's bill when it is put down into the nest; if the adult is not ready to regurgitate, it will free itself and raise the head beyond reach. When the young are about four weeks old and are well feathered, the yak-yak gives way to a coarse squawk. It is not as constant as either of the other two sounds but is used during an argument in the nest or when the adult approaches with food, but stops when the adult leaves. At this stage, as the adult lands on the nest, the young stand, raise their crests and jab at the bill of the adult. Occasionally when the adult lands on a nearby limb the young reach out toward it, and, as it walks to the nest the neck is held stiffly erect.

## GROWTH OF YOUNG

The young grow rapidly and at the age of four weeks the top of the head, back of neck and the back are dark gray. The legs, breast and front of neck are light in color but heavily streaked with red-brown. The upper mandible is gray but the lower mandible shows some yellow at its base. After six weeks, the feathers are nearly fully developed and the young birds stand on the edge of the nest and flap their wings, often jumping from one side of the nest to the other. They do not venture out onto the tree limbs. A few may flap their wings strongly enough to raise their feet from the nest. Although they still peck at each other's bills it is not as commonly done as before. It is at this age that they start the howling noise of the adults, except that it is shorter in duration, higher in pitch and is not accompanied by the swaying of the body. The call often ends in two or three short squawks.

At the age of seven weeks the young pull at sticks in the nest, even

removing one and putting it in a different place. Occasionally one will venture onto a nearby branch, but their actions are shaky and unbalanced. Soon after they get out onto the tree branches, they take short hop-flights from one branch to another; at the age of eight weeks they are fully feathered and able to leave the nesting tree.

After the young leave the nest they are completely independent although a few may return occasionally. Immature birds of the previous year were often seen feeding in ponds but they seldom appeared in the Wabaunsee colony. On April 25 one immature bird came into the area and stood for several minutes on the edge of the nest with an incubating bird, but suddenly the adult rose and drove it away. On May 5 two immature birds appeared but were neither accepted nor rejected as long as they did not approach a nest.

## Results

Out of the 45 nests that could be observed in the Wabaunsee colony, two were abandoned shortly after the eggs were laid. These nests were not included in the egg count in Table 5, nor were the four eggs in a nest built later. Of the 164 eggs in these 42 nests, 91 young are known to have fledged, only 55.5 percent of the total eggs layed. The number of birds fledged was low because one set of four eggs did not hatch and six nests with young were destroyed by wind, with a loss of 18 birds.

## Acknowledgments

A great deal of credit for the information and confirmation of facts goes to Jack Knouse, student at Emporia State University, who was killed in an automobile accident in 1962. Ted F. Andrews, John Breukelman and David F. Parmelee, Emporia State University, gave special help and encouragement. The 1973 and 1978 nest counts could not have been made without the help of Stanley Roth, Jr., Biology teacher at Lawrence High School and several of his students. He, too, has given valuable assistance in the compilation of data and in reading the manuscript. Special appreciation goes to the Fish and Game Commission for their aid in financing the 1978 nest count and for information from many of their members. Among these, Marvin Schwilling, nongame biologist, has been valuable in reporting colonies and in reading the manuscript. I am also indebted to many members of the Kansas Ornithological Society for information, to farmers who gave information and permission to enter their property and to the U.S. Geological Survey in Lawrence for the rainfall and groundwater information.

## References

Andrews, Ted F., and Homer A. Stephens. 1956. Colonies of the Great Blue Heron (*Ardea herodias*) in Kansas. Trans. Kans. Acad. Sci. 59:279–308.

Breukelman, John. 1951. Heron colony in Chase County. Kansas Ornith. Soc. Bull. II(3):30.

Cottrille, W. Powell, and Betty Darling Cottrille. 1958. Museum of Zoology. Univ. Mich. Bull. No. 102, 15 pp.

Graber, Jean W., Richard R. Graber, and Ethelyn L. Kirk. 1978. Illinois birds: Ciconiiformes. Biological Notes No. 109, Illinois Natural History Survey, Urbana.

Kirkpatrick, C. M. 1940. Some food of the young Great Blue Heron. American Midland Naturalist 24:594–601.

Lowe, Frank A. 1954. The Heron. Collins, St. James Place, London, 178 pp.

Schwilling, Marvin D. 1953. A Heron rookery observed in western Kansas. Kansas Ornith. Soc. Bull. IV(4):36.

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# Mr. Pitt's Telescope: A Short History of the 27-Inch Reflector at the University of Kansas

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ABSTRACT

The history of the University of Kansas' 27-inch reflecting telescope is traced from its beginnings in the drained, basement swimming pool of a talented Kansas City amateur astronomer, William Pitt, to its removal to its present location on the top of Lindley Hall in Lawrence under the supervision of Prof. N. W. Storer. Emphasis is placed on the early attempt by Dr. Dinsmore Alter to develop the University of Kansas' Observatory into a self-sustaining, first-class research facility and on those circumstances and events which have ultimately led to its evolution into a public relations showpiece and teaching telescope.

As they enter, visitors to the University of Kansas' Observatory are greeted by a bronze plaque introducing them to the William Pitt 27-inch reflecting telescope. Few such individuals, upon leaving however, do so with an appreciation of the history and "romance," to use the word of former Professor of Astronomy, Dinsmore Alter, associated with this telescope. As Visiting Professor of Astronomy during the 1978–79 academic year, the writer had an opportunity to trace the development of the University's principal optical instrument and found it both a fascinating and, from an astronomer's point of view, often frustrating tale. This short article attempts to present the reader with a brief look at both these aspects of the story.

While the study of astronomy at the University of Kansas dates from 1876, the first observatory building on campus was not erected until about 1885. Built on land deeded to the University by the State of Kansas, this structure, which really amounted to no more than a simple wooden shed with a slit roof, housed a 6-inch Alvan Clark refractor and a 2-inch transit telescope. The lifetime of the new observatory was extremely short, for within a year Gov. Robinson rescinded the gift of land upon which the building had been erected, and the structure was razed. From this time until 1919, the University had no permanent structure from which to make astronomical observations, although the teaching of astronomy was continued

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under the direction of a number of individuals, among them Prof. E. L. Nichols, the founder of the *Physical Review*.

## 1918–1935: The Alter Years

In 1918, after serving two years with the artillery corps, Dr. Dinsmore Alter rejoined the University faculty, having been hired in 1916 just prior to the outbreak of hostilities between the United States and Germany. One of Prof. Alter's first official acts was to secure from the state legislature an appropriation of $3500 for the construction of a new observatory building and the purchase of a new 3-inch transit instrument and an equatorial mount for the 6-inch Clark refractor. The building, completed in the fall of 1919, occupied the site upon which the University's large Hoch Auditorium now stands.

Throughout his 17 year association with the University, Alter, whose principal research interest was the computation of asteroid orbits, cherished the hope of creating an active program of asteroidal and cometary research in Lawrence. In a letter to then Chancellor Frank Strong dated May 28, 1919, he described the first step in fulfilling his dream: the construction of a 20-inch reflecting telescope. As outlined in his letter, Alter agreed to purchase, grind and figure the primary mirror for the instrument and then to donate it to the University, contingent upon the latter's purchase of an appropriate mounting and construction of an additional dome in which to house the telescope. A 1.6-inch thick blank was shortly thereafter purchased from the Pittsburg Plate Glass Co., and the grinding was begun in 1920, only to be abandoned soon afterward when it appeared that no mounting would be forthcoming from the University.

In the fall of 1925, undaunted, Alter approached Mr. W. Y. Morgan, a member of the Kansas Board of Regents, with a plan for a new observatory and a proposal for a program of astronomical research for the University. To implement the proposal, which had been endorsed by some of the leading astronomers of the day, including W. S. Adams of Mt. Wilson, E. B. Frost of Yerkes, R. G. Aitken of Lick and Harlow Shapley of Harvard, required an estimated total of $850,000, $210,000 of which Alter hoped to secure by an outright gift to purchase, among other things, a 36-inch reflector; the remainder of the $850,000 was to go into an endowment fund, the interest from which was to be used to provide salaries for two additional astronomers and a staff of computers, whose primary efforts would be directed towards the determination of accurate asteroid orbits. As with his previous efforts, Alter was not successful in securing the necessary financial backing for his program, and no equipment or staff was added at this time. Indeed, in 1926, the Observatory was razed for the second time to make room for a new auditorium (Hoch), and rebuilt west of Marvin Hall.

It was in the same year, 1926, that Alter (probably through the interces-

Fig. 1. Looking east along Jayhawk Boulevard, the campus of the University of Kansas is shown above as it appeared in May of 1925. The Observatory (lower right foreground) at this time housed a 6-inch Clark refractor and a 3-inch transit instrument, and occupied the site on which Hoch Auditorium now stands. Just east of the Observatory is old Haworth Hall, while across the street stands the newly completed Strong Hall, named after Chancellor Frank Strong. As noted in the text, the Observatory was razed to make room for Hoch and moved to a location just west of Marvin Hall, from which this picture was taken. (Photograph from Taft's "Life on Mount Oread," p. 133, courtesy of the University of Kansas Archives.)

sion of Thornton Cooke, then President of the Columbia National Bank and a KU alumnus) first met Mr. William Pitt, a retired Kansas City businessman who, as founder of the Irving-Pitt Manufacturing Co., had made his fortune producing spiral notebooks. Mr. Pitt, an amateur astronomer and talented machinist, having learned of Alter's needs, agreed to donate both his time and money toward the construction of two large mirrors to be used for the study of asteroids. The first mirror to be completed by Pitt was the 20-inch plate glass disk originally purchased by Alter in 1920; in the course of this initial work, Pitt designed and built his own precision grinding machine, and perfected his polishing and figuring techniques. In 1928, encouraged by the favorable results of the 20-inch mirror project, Pitt undertook a more ambitious project on behalf of the University: the grinding and polishing of a 27-inch mirror.

Originally, Alter and Pitt had hoped to acquire a clear quartz disk of the appropriate size to be used as the primary of the new instrument. Failing in this endeavor, it was decided to achieve the high degree of thermal stability required of telescope mirrors by using a disk made of Pyrex. The disk,

Fig. 2. Mr. William Pitt (left) and Professor Dinsmore Alter at work on the 27-inch mirror in Mr. Pitt's emptied swimming pool laboratory. The grinding machine pictured was entirely designed and built by Mr. Pitt. (Photograph from *The Kansas Engineer* [March 1928], p. 14, courtesy of the University of Kansas Archives.)

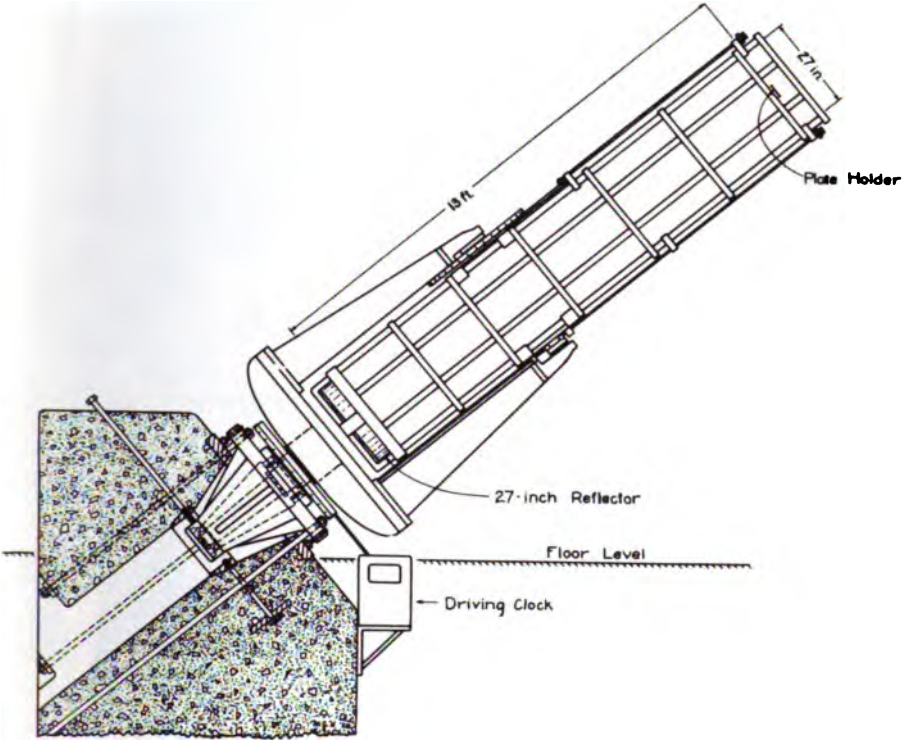


Fig. 3. This drawing, a plan view of the Pitt telescope by Manley J. Hood, who carried out the majority of the mechanical design and construction of the telescope, shows the instrument in its original prime focus configuration. Subsequent photos of the telescope show it after its conversion to a Newtonian reflector under the supervision of the late Professor N. Wyman Storer. (Photograph from *The Kansas Engineer* [March 1928], p. 15, courtesy of the University of Kansas Archives.)

arriving in Kansas City in January 1928, weighed about 250 pounds, and was 27.5 inches in diameter and 4.5 inches thick; it cost $250. The grinding and polishing of the blank was carried out in Mr Pitt's home in Kansas City—specifically in an emptied swimming pool in the amateur astronomer's basement. For over a year, Pitt and an assistant carried out the grinding, polishing and figuring of the mirror. By February 1929, knife edge tests conducted by Alter and Pitt indicated that the desired paraboloidal figure had been nearly achieved. Shortly thereafter, the 27-inch mirror was transported to Lawrence for installation at the Observatory. At the time of its installation in 1929, the William Pitt–University of Kansas 27-inch telescope was the first telescope to have its main light-gathering element made of Pyrex, although a 16-inch secondary mirror made of Pyrex was in use at Mt. Wilson at the time.

Fig. 4. This photograph, taken in the fall of 1958, shows the William Pitt telescope after its removal to the roof of Lindley Hall. Professor Storer, who, for 35 years until his retirement in 1970, served as director of the observatory, is shown at the lower right; at the eyepiece is Robert M. Krisko (BA—Astronomy, 1960). The present Lindley Hall observing facilities (shown in more detail in subsequent photographs) were largely designed by Storer and remain virtually unchanged since their construction. (Photograph courtesy of the University of Kansas Archives.)

Fig. 5. Visitors to the University of Kansas' Observatory are greeted by this bronze plaque on the entrance door to the 27-inch telescope dome. Originally attached to the telescope at the time of its dedication in 1939, the plaque commemorates the efforts of Mr. William Pitt during the construction of the 27-inch reflector. (This and all subsequent photos by the author.)

In a very real sense, the University's 27-inch telescope was a home-made instrument. Not only was the mirror fashioned locally, but the fork mounting was designed and largely constructed by University personnel. Manley Hood, a 1929 graduate of the University, and his brother, Henry, designed and machined the vast majority of the telescope parts in the University's Fowler Shops; only two of the large castings required for the instrument had to be made in Kansas City. The original drive for the telescope was contributed by Mr. Pitt himself and then improved in 1935 by an electrical engineering student, William Edson. Even the turning mechanism for the 27-inch dome was a collaborative effort by several University Departments: the Electrical Engineering Department donated the main driving motor, the Buildings and Grounds Department contributed a large gearing mechanism from an old concrete mixer, and the Mechanical Engineering Department provided the facilities which allowed Henry Hood to rebuild these diverse elements into a satisfactory dome rotation device.

Unfortunately, and despite the best cooperative efforts of the University staff, progress on the telescope ground to a halt just short of completion in 1930 due to economic difficulties caused by the Depression. As Prof. Alter wrote in 1934, ". . . a very small amount of money prevents the University

Fig. 6. High atop Lindley Hall, the domes of the University of Kansas Observatory can be seen in this photograph taken facing north. At the left is the dome for the 6-inch Clark refractor, while at the right is that housing the 27-inch William Pitt reflector. Beginning in early 1980, the 6-inch dome will be dismantled and replaced with a new 16-foot diameter aluminum dome and cylinder. The observing slit for the 3-inch transit instrument is just visible about midway between the two observatory domes.

of Kansas from having the prestige of the largest telescope within several hundred miles of Lawrence. When the Depression made it impossible to use more of the University's funds, the William Pitt–University of Kansas 27-inch reflecting telescope lacked only a few minor parts, an observing chair, a complicated plate-holder and a plate measuring machine of being ready to start on its nightly career of research work." Alter estimated that an additional $500–800 was needed to bring the telescope into full operation; once again, the money was not forthcoming. In 1935, Dr. Alter took a leave of absence from the University, and, a year later, resigned to become the Director of the Griffith Observatory in Los Angeles. The telescope still remained incomplete and, after almost 17 years of continuous effort, the research observatory envisioned by Prof. Alter had yet to be established. As it turned out, it never would be.

## 1935–Present: Completion, Relocation, and Renovation

The job of completing the telescope fell to Alter's replacement, Dr. N. Wyman Storer, who, like Alter, was a graduate of the University of California. Among the first things Storer did was to have the 27-inch mirror aluminized. The history of the aluminization of the 27-inch mirror, although short, is, like much of the history of the whole instrument, an interesting one. In the spring of 1934, Alter had approached Dr. John Strong, a 1926 graduate of the University of Kansas, and then a faculty member at Cali-

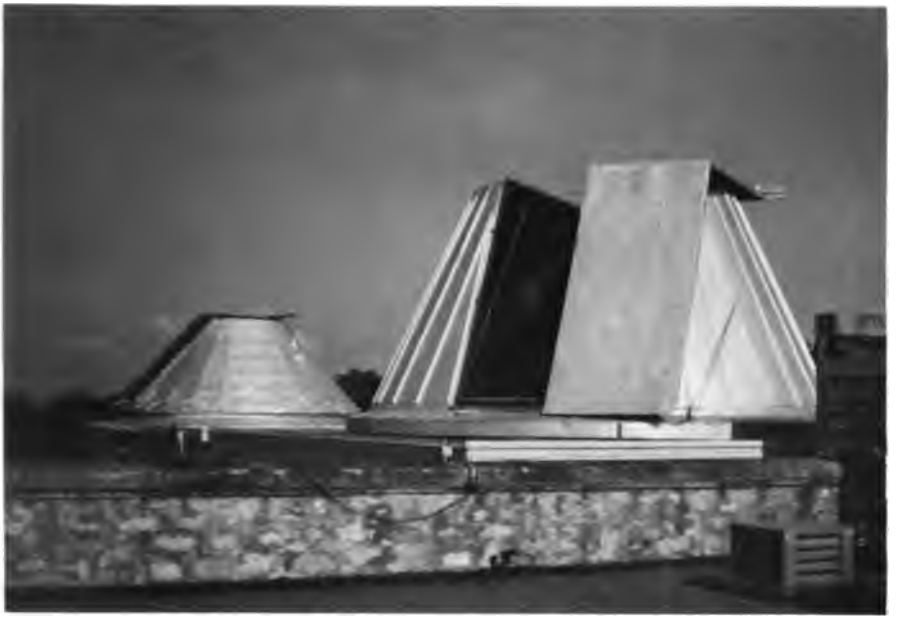

Fig. 7. This close-up of the Observatory domes, taken from the roof of Lindley Hall, shows the William Pitt 27-inch telescope in the larger building on the right. Both domes were designed and built under the direction of Dr. Storer, and consist of wooden frames overlaid with aluminum flashing and/or painted canvas. The shutters are rolled aside on a pair of steel rails through use of a pulley system, a part of which (the white nylon cording just inside the slit) can be seen in the photograph.

fornia Institute of Technology, about the possibility of having the 27-inch mirror aluminized. Strong, who had recently developed a new vacuum aluminization process, agreed to try out his technique on the primary of the Pitt telescope free of charge, if the University would pay the shipping charges to and from Pasadena. Negotiations over the details of the aluminization were temporarily halted during Alter's leave of absence and were not taken up again until 1936, when Storer re-established Strong's willingness to finish the mirror. The 27-inch paraboloid was duly shipped to Pasadena and returned to Lawrence on July 17, 1937, with a newly coated aluminum surface.

In the year and a half separating the installation of the aluminized 27-inch mirror and the formal dedication of the Pitt reflector on February 17, 1939, the last obstacles preventing the use of the telescope were gradually overcome. In April of 1938, an observing platform was built which provided convenient access to the prime focus position of the telescope, then the only available observing station. Between September of 1938 and the spring of 1939, an offset guider, a shuttered plate holder, and knife-edge tester/

Fig. 8. This view of the 27-inch refractor taken through the shutter opening shows in more detail the pulley system mentioned in Figure 7, as well as the fine motion and clamping controls (the large circular knobs at the middle left) of the telescope. Just above these controls is the

field viewer were all constructed and put into use. Again, from an historical point of view, this last phase of development is also of interest because it was carried out largely by Clyde W. Tombaugh, the man who had discovered Pluto in 1930, as part of his Master's thesis work. Finally, after almost 10 years of work, the 27-inch telescope was ready for regular use. At a meeting of the Society of the Sigma Xi on February 17, 1939, the instrument was dedicated as the "William Pitt 27-inch Telescope" in recognition of Mr. Pitt's contribution to the project. As Prof. Storer wrote in 1938 urging that the telescope be named after Pitt: "By far the greatest value of the telescope lies in the glass, and since Mr. Pitt was so vitally interested in the completion of that, it is entirely fitting that the whole telescope be named after him." At the time of the dedication, the bronze plaque which now welcomes visitors to the Observatory was attached to the telescope, and Dr. Harold Hungerford, then president of the Kansas Chapter of Sigma Xi, presented a medal to Mr. Pitt (who was living in New Jersey at the time) in recognition of his interest in science.

In the more than 40 years since its dedication, the Pitt telescope has continued to lead an up and down life. Although the location of the Observatory in 1939 was by no means ideal, a point Tombaugh made rather strongly in his dissertation (". . . the writer sees little hope of much more useful research being accomplished until the telescope is moved to a more favorable location which would be free of obnoxious lights and dust."), the telescope was at least able to be used there. But not for long. In 1944, the University of Kansas' Observatory was razed a third time after the completion of Lindley Hall, just to the west. At this time, the 6-inch refractor was removed to the roof of Lindley and the Pitt reflector, as well as the 3-inch transit telescope were placed in storage in the basement of Hoch Auditorium. For over 7 years, the 27-inch remained in "mothballs." Finally, in the spring of 1952, construction of a new observatory building to house the telescope was completed, and, after several months of alignment and adjustment, the newly housed instrument was put back into service.

Since that time, the Pitt telescope has been in nearly continuous use. Over the years, in addition to having been converted for use as a Newtonian reflector, the 27-inch has acquired an assortment of auxiliary equipment, mainly through the efforts of Storer and Prof. Henry Horak; such equipment

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main observing port for the instrument. Although an eyepiece is shown attached to the port in this photograph, direct photography and multi-color photometry can also be carried out from this position. Originally left open and unshielded, the telescope tube supporting frame is now sheathed with blue canvas to reduce the amount of scattered light and windblown dust which reach the mirror during operation.

Fig. 9. From inside the dome, some details of the opposite side of the 27-inch telescope can be seen in this picture. In particular, a second observing port (usually used for spectroscopic work but shown here set up for visual work) is evident, as well as the electronic control panel (lower middle right) for the telescope which provides for dome rotation, East-West slewing motion and drive rate variation. The secondary mirror of the telescope is attached to its supporting structure by a pivot and can be rotated 90° between the two observing ports so that instrument changes to accommodate different observing programs can be minimized.

includes a photoelectric photometer, a grating spectrograph, and an assortment of plateholders for direct photography. And, although much of this instrumentation is now over twenty years old, it is still used on a regular basis by students and members of the local amateur astronomical society.

## Summary: The Future of the Pitt Telescope

Despite these additions and improvements, the William Pitt 27-inch reflector has never been used extensively as a research tool as originally planned; instead it has functioned largely in the dual roles of an instructional instrument used to teach undergraduate astronomy students proper observing techniques and a University showpiece used to reveal the beauty and mystery of the Universe to "open house" visitors to the Observatory. Given the steady deterioration in the sky conditions in Lawrence due to air and light pollution caused by an ever growing University campus and city population, and the ever present shortage of funds to maintain and update the nearly 30-year old facility, it is unlikely that the nature or the use of the Pitt telescope will change in the foreseeable future.

The history of the William Pitt–University of Kansas 27-inch telescope is a truly remarkable and yet somewhat unsatisfying tale. It is remarkable in terms of the way in which the instrument was designed and constructed, as well as in terms of the personalities involved in the instrument's completion; it is frustrating and unsatisfying (at least from an astronomer's point of view) insofar as it ends with the initial purposes of the builders unfulfilled. In particular, due to changes in University priorities and fluctuations in the levels of funding inside and outside the University for astronomical activities, the self-sustaining, first-class research facility in astronomy envisioned by Alter, Storer, and others, has never been achieved. And, while an excellent teaching program in astronomy has been maintained to the present through the efforts of individuals like Alter, Storer, Horak, Prof. P. Wehinger, and now Prof. S. J. Shawl, it is more than a little saddening to contemplate the losses to midwestern research in astronomy engendered by the failure to capitalize on Mr. Pitt's telescope.

## Acknowledgments

The author wishes to acknowledge the support and assistance of the Department of Physics and Astronomy at the University of Kansas during the time in which this short history was being prepared. In this regard, special thanks are due to Dr. J. P. Davidson, Chairman of the Department, for his continued encouragement and guidance while this work was being carried out. The staff of the University Archives at the Kenneth E. Spencer Research Library of the University of Kansas is also recognized for their kind cooperation and assistance in securing for the author the many documents and pieces of correspondence upon which this article is based.

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# Food Habits of the Flathead Catfish, *Pylodictis olivaris* (Rafinesque), in Relation to Length and Season in a Large Kansas Reservoir

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ABSTRACT

Frequency of occurrence, numbers, and volumes of organisms in stomachs of various age and size groups of 172 flathead catfish (*Pylodictis olivaris*) from Milford Reservoir in northcentral Kansas were determined for each month from April through November 1975. Flathead catfish between 201 and 500 mm consumed mostly benthic macroinvertebrates and fishes, while those over 500 mm almost exclusively are gizzard shad (*Dorosoma cepedianum*). Diets of piscivorous flathead catfish appeared to shift seasonally. Two-year-old flathead catfish relied heavily on large benthic macroinvertebrates such as crayfish (*Orconectes* sp.) but this dependence decreased gradually until age six, when the flathead catfish were almost entirely piscivorous. Changes in food habits may be related to physical size of the predator and physical exclusion from habitat occupied by crayfish. The flathead catfish did not prey actively on rough fish populations, probably because gizzard shad of small size were readily available. The relatively fast growth of flathead catfish in Milford Reservoir suggests that an abundance of forage fishes limited competition for food.

The flathead catfish (*Pylodictis olivaris*) is commonly found in rivers of eastern Kansas and specimens weighing more than 18.1 kg (40 pounds) are taken from rivers in the state each year. Because of its fighting ability, edibility, and potential for reaching a large size, the flathead catfish is held in high regard by fishermen (McCoy, 1953). A creel census showed 1755 flathead catfish averaging 4.41 kg each, and totalling 7494 kg were harvested in 1974 from Milford Reservoir, Kansas (Groen, personal communication).

Brown and Dendy (1961) found that flathead catfish from Alabama rivers were mainly piscivorous. Other authors suggest that the actual abundance

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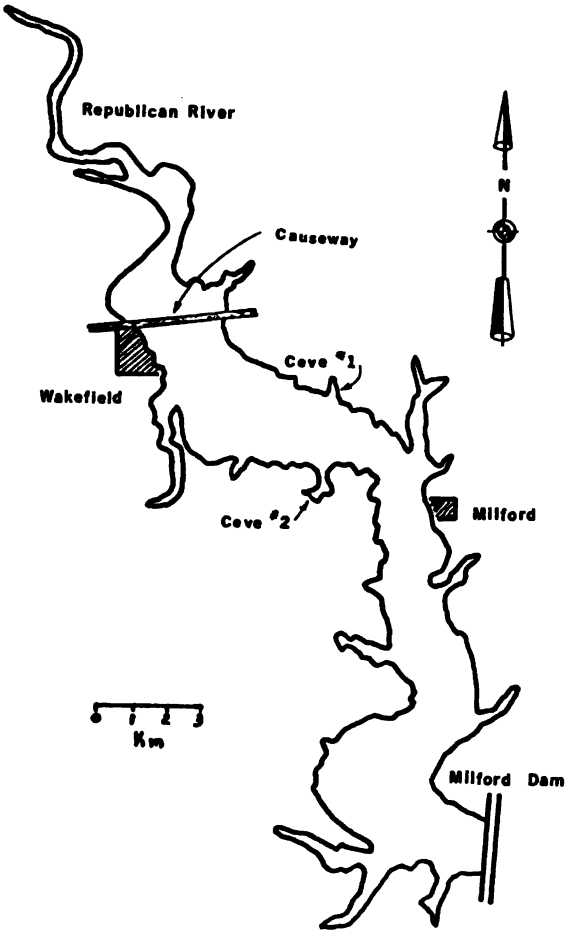


Fig. 1. Map of Milford Reservoir.

of forage fishes (Langemeier, 1965) or the relative abundance of forage fishes and invertebrates (Minckley and Deacon, 1959) influences the food selected by flathead catfish. Swingle (1967) indicated that all catfish should be placed in the carnivorous classification for population analysis. Turner and Summerfelt (1970) found flathead catfish greater than 500 mm (19.7 inches) to feed exclusively on gizzard shad (*Dorosoma cepedianum*) and freshwater drum (*Aplodinotus grunniens*) in Oklahoma reservoirs. Flathead catfish under 102 mm (four inches) from the Big Blue River in Kansas contained mostly larvae of Ephemeroptera, Trichoptera, and Diptera. Crayfish and fish were most abundant in flatheads between 104 mm (4.1 inches) and 254

Table 1. Volumetric analysis of food items found in 172 flathead catfish stomachs from various lengths groups.

| Food items | Length group (mm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 301–400 | 401–500 | 501–600 | 601–700 | 701–800 | 801–900 | 901–1000 | 1001–1100 | Totals |
| Crayfish | 44.0* | 50.4 | 0.1 | | | | | | 94.5 |
| | 40.1** | 37.4 | 0.1 | | | | | | 7.0 |
| Gizzard shad | 60.0 | 72.9 | 114.5 | 258.2 | 425.0 | | 80.0 | | 1010.6 |
| | 54.7 | 54.0 | 90.4 | 94.6 | 74.6 | | 81.3 | | 74.9 |
| Unrecognizable tissue | 0.5 | 7.6 | 2.3 | 8.9 | 16.3 | 1.0 | 9.3 | 2.0 | 47.9 |
| | 0.5 | 5.6 | 1.8 | 3.3 | 2.9 | 3.7 | 9.4 | 20.0 | 3.6 |
| Unrecognizable fish | 3.0 | 3.0 | 9.1 | 2.0 | 5.2 | 3.8 | | 8.0 | 34.1 |
| | 2.7 | 2.2 | 7.2 | 0.7 | 0.9 | 14.2 | | 80.0 | 2.5 |
| Plant tissue | 2.2 | 1.0 | | 1.7 | | | | | 4.9 |
| | 2.0 | 0.7 | | 0.6 | | | | | 0.4 |
| Insects and larvae | | | 0.7 | | | | | | 0.7 |
| | | | 0.6 | | | | | | 0.1 |
| Channel catfish | | | | 2.0 | | | | | 2.0 |
| | | | | 0.7 | | | | | 0.1 |
| Drum | | | | | 27.0 | | 9.3 | | 36.3 |
| | | | | | 4.7 | | 9.4 | | 2.7 |
| Flathead catfish | | | | | 42.0 | | | | 42.0 |
| | | | | | 7.4 | | | | 3.1 |
| Green sunfish | | | | | | 22.0 | | | 22.0 |
| | | | | | | 82.1 | | | 1.6 |
| Carp | | | | | 54.0 | | | | 54.0 |
| | | | | | 9.5 | | | | 4.0 |
| Total volume | 109.7 | 134.9 | 126.7 | 272.8 | 569.5 | 26.8 | 98.6 | 10.0 | 1349.0 |
| | 8.1 | 10.0 | 9.4 | 20.2 | 42.1 | 2.0 | 7.3 | 0.7 | 100.0 |
| No. of stomachs examined for each length group | 38 | 37 | 20 | 22 | 28 | 9 | 11 | 5 | 170 |

* Volume in milliliters.
** Percent of volume.

mm (10 inches). Larger fish from the same river appeared to be entirely piscivorous (Minckley and Deacon, 1959). In the Neosho River, Minckley and Deacon (1959) found that flathead catfish from 104 mm (4.1 inches) to 254 mm (10 inches) relied mainly of Ephemeroptera nymphs for food. Clemons (1954) examined six flathead catfish from Oklahoma reservoirs and found three contained insects and three unidentified fishes.

Information on feeding habits of reservoir populations of flathead catfish is limited to the studies of Clemons (1954) and Turner and Sumerfelt (1970)

Table 2. Total lengths of gizzard shad found in stomachs of various length groups of flathead catfish.

| Length group of flathead catfish | No. of measurable shad in stomachs | Length range in mm | Avg. length |
|---|---|---|---|
| 301–400 | 12 | 41–110 | 70 |
| 401–500 | 23 | 31–79 | 56 |
| 501–600 | 12 | 41–111 | 76 |
| 601–700 | 30 | 30–246 | 69 |
| 701–800 | 8 | 78–215 | 142 |
| 801–900 | — | — | — |
| 901–1000 | 3 | 95–166 | 128 |

Table 3. Frequency of occurrence and numerical analysis by month of stomach contents from flathead catfish in the 301–400 mm length group.

| Food items | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Crayfish | | | | 3 (50)* | 9 (47) | | | | 12 (46) |
| | | | | 3 (75)** | 10 (43) | | | | 13 (48) |
| Gizzard shad | | | | 1 (17) | 4 (21) | | | | 5 (19) |
| | | | | 1 (25) | 11 (48) | | | | 12 (44) |
| Unrecognizable fish | | | | | 2 (11) | | | | 2 (08) |
| | | | | | 2 (09) | | | | 2 (07) |
| Insects and larvae | | | | | | | | | |
| Channel catfish | | | | | | | | | |
| Drum | | | | | | | | | |
| Flathead catfish | | | | | | | | | |
| Green sunfish | | | | | | | | | |
| Carp | | | | | | | | | |
| Plant tissue | | | | | 2 (11) | | | | 2 (08) |
| | | | | | — | | | | — |
| Unrecognizable tissue | | | 1 (100) | 2 (33) | 2 (11) | | | | 5 (19) |
| | | | — | — | — | | | | — |
| Total no. of stomachs containing food | | | 1 | 6 | 19 | | | | 26 |
| Total no. of organisms in stomachs | | | 0 | 4 | 23 | | | | 27 |

* Frequency of occurrence.
** Numerical analysis.
( ) Percentage frequency of occurrence or percentage numerical analysis, rounded to nearest whole percent.

Table 4. Frequency of occurrence and numerical analysis by month of stomach contents from flathead catfish in the 401–500 mm length group.

| Food items | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Crayfish | | | 2 (67)* | 6 (43) | 2 (10) | | | | 10 (26) |
| | | | 2 (67)** | 7 (50) | 2 (09) | | | | 11 (28) |
| Gizzard shad | | | 1 (33) | 5 (36) | 11 (52) | | | | 17 (45) |
| | | | 1 (33) | 7 (50) | 17 (77) | | | | 25 (64) |
| Unrecognizable fish | | | | | 2 (10) | | | | 2 (05) |
| | | | | | 3 (14) | | | | 3 (08) |
| Insects and larvae | | | | | | | | | |
| Channel catfish | | | | | | | | | |
| Drum | | | | | | | | | |
| Flathead catfish | | | | | | | | | |
| Green sunfish | | | | | | | | | |
| Plant tissue | | | | | 1 (05) | | | | 1 (03) |
| | | | | | — | | | | — |
| Unrecognizable tissue | | | | 3 (21) | 5 (24) | | | | 8 (21) |
| | | | | — | — | | | | — |
| Total no. of stomachs containing food | | | 3 | 14 | 21 | | | | 38 |
| Total no. of organisms in stomachs | | | 3 | 14 | 22 | | | | 39 |

* Frequency of occurrence.
** Numerical analysis.
( ) Percentage frequency of occurrence or percentage numerical analysis, rounded to nearest whole percent.

in Oklahoma. The lack of literature concerning food habits of flathead catfish in large impoundments and a paucity of age and growth data stimulated this study.

## Description of Study Area

Milford Reservoir (Fig. 1) was impounded in 1967 by the U.S. Army Corps of Engineers for flood control. The dam is located 6.4 kilometers northwest of Junction City, Kansas on the Republican River, 12.9 kilometers above the Republican's junction with the Smoky Hill River. Milford Reservoir at conservation level has a surface area of 6486 hectares and 262 kilometers of shoreline.

Although Milford Reservoir is probably eutrophic it occasionally appeared to be phosphorus limited (Environmental Protection Agency, 1977). Only slight impairment of productivity exists due to suspended solids. This

Table 5. Frequency of occurrence and numerical analysis by month of stomach contents from flathead catfish in the 501–600 mm length group.

| Food items | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Crayfish | | | | 1 (17)* | | | | | 1 (05) |
| | | | | 1 (20)** | | | | | 1 (05) |
| Gizzard shad | | 1 (100) | 1 (100) | 1 (17) | 3 (50) | | 2 (50) | 1 (100) | 9 (45) |
| | | 1 (100) | 1 (100) | 1 (20) | 4 (80) | | 3 (75) | 4 (100) | 14 (70) |
| Unrecognizable fish | | | | | 1 (17) | | 1 (25) | | 2 (10) |
| | | | | | 1 (20) | | 1 (25) | | 2 (10) |
| Insects and larvae | | | | 2 (33) | | | | | 2 (10) |
| | | | | 3 (60) | | | | | 3 (15) |
| Channel catfish | | | | | | | | | |
| Drum | | | | | | | | | |
| Flathead catfish | | | | | | | | | |
| Green sunfish | | | | | | | | | |
| Carp | | | | | | | | | |
| Plant tissue | | | | | | | | | |
| Unrecognizable tissue | | | | 2 (33) | 2 (33) | 1 (100) | 1 (25) | | 6 (30) |
| | | | | — | — | — | — | | — |
| Total no. of stomachs containing food | | 1 | 1 | 6 | 6 | 1 | 4 | 1 | 20 |
| Total no. of organisms in stomachs | | 1 | 1 | 5 | 5 | — | 4 | 4 | 20 |

* Frequency of occurrence.
** Numerical analysis.
( ) Percentage frequency of occurrence or percentage numerical analysis, rounded to nearest whole percent.

is probably due to the low flow exhibited by the Republican River throughout much of the year. During periods of high runoff turbidity limits production. Milford undergoes drastic water level fluctuations which strongly influence the fisheries potential of the lake. Some organic pollution is received from untreated sewage effluent from several small communities (Layher et al., 1978).

A geological and physical description of the Lower Republican River Basin, in which Milford Reservoir lies, can be found in Jones and Ebert (1977).

The flathead catfish used in this study came from the upper end of the reservoir above the town of Milford. The majority were taken near the causeway (landfill bridge) which crosses the reservoir at Wakefield (Fig. 1).

Table 6. Frequency of occurrence and numerical analysis by month of stomach contents from flathead catfish in the 601–700 mm length group.

| Food items | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Crayfish | | | | | | | | | |
| Gizzard shad | | | | 3 (50)*<br>12 (92)** | 4 (57)<br>15 (88) | 1 (50)<br>3 (100) | | | 8 (36)<br>30 (91) |
| Unrecognizable fish | | | | 1 (17)<br>1 (08) | 1 (14)<br>1 (06) | | | | 2 (09)<br>2 (06) |
| Insects and larvae | | | | | | | | | |
| Channel catfish | | | | | 1 (14)<br>1 (06) | | | | 1 (05)<br>1 (03) |
| Drum | | | | | | | | | |
| Flathead catfish | | | | | | | | | |
| Green sunfish | | | | | | | | | |
| Carp | | | | | | | | | |
| Plant tissue | | 2 (50)<br>— | | | | | | | 2 (09)<br>— |
| Unrecognizable tissue | | 2 (50)<br>— | 2 (100)<br>— | 2 (33)<br>— | 1 (14)<br>— | 1 (50)<br>— | | 1 (100)<br>— | 9 (41)<br>— |
| Total no. of stomachs containing food | | 4 | 2 | 6 | 7 | 2 | | 1 | 22 |
| Total no. of organisms in stomachs | | — | — | 13 | 17 | 3 | | — | 33 |

* Frequency of occurrence.
** Numerical analysis.
( ) Percentage frequency of occurrence or percentage numerical analysis, rounded to nearest whole percent.

## Materials and Methods

Two hundred flathead catfish were collected from Milford Reservoir from April through November 1975. Of this number, 102 were taken on rod and reel from the causeway which crosses the north end of the lake (Fig. 1). Thirty-nine flathead catfish were taken on trotlines from the area of submerged timber at the mouth of the Republican River. Trammel and gill nets set parallel and perpendicular to the causeway and across the old river channel in the timbered area each caught twenty-three fish. The trammel net had a small mesh of 8.89 cm, a large mesh of 30.48 cm and was 91.44 meters long. It was set on April 18, May 28, July 12, 13, August 6, 12, 13.

Table 7. Frequency of occurrence and numerical analysis by month of stomach contents from flathead catfish in the 701–800 mm length group.

| Food items | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Crayfish | | | | | | | | | |
| Gizzard shad | 1 (33)* | 1 (14) | | | 2 (67) | | | 2 (40) | 6 (30) |
| | 2 (100)** | 2 (33) | | | 2 (100) | | | 4 (80) | 10 (63) |
| Unrecognizable fish | | 1 (14) | 1 (100) | | | | | 1 (20) | 3 (15) |
| | | 1 (17) | 1 (100) | | | | | 1 (20) | 3 (19) |
| Insects and larvae | | | | | | | | | |
| Channel catfish | | | | | | | | | |
| Drum | | 1 (14) | | | | | | | 1 (05) |
| | | 1 (17) | | | | | | | 1 (06) |
| Flathead catfish | | 1 (14) | | | | | | | 1 (05) |
| | | 1 (17) | | | | | | | 1 (06) |
| Green sunfish | | | | | | | | | |
| Carp | | 1 (14) | | | | | | | 1 (05) |
| | | 1 (17) | | | | | | | 1 (06) |
| Plant tissue | | | | | | | | | |
| Unrecognizable tissue | 2 (67) | 2 (29) | | 1 (100) | 1 (33) | | | 2 (40) | 8 (40) |
| | — | — | | — | — | | | — | — |
| Total no. of stomachs containing food | 3 | 7 | 1 | 1 | 3 | | | 5 | 20 |
| Total no. of organisms in stomachs | 2 | 6 | 1 | — | 2 | | | 5 | 16 |

* Frequency of occurrence.
** Numerical analysis.
( ) Percentage frequency of occurrence or percentage numerical analysis, rounded to nearest whole percent.

All nets were checked every 12 to 24 hours. Six gill nets 9.14 meters long with mesh sizes from 2.54 cm to 8.89 cm in size were tied together and set on May 28 and June 29. On September 16 274 meters of gill nets with meshes of 7.62, 8.89, and 10.1 cm were employed. On November 6 and 7 a gill net with 10.1 cm mesh was set. An additional 13 fish were collected from two cove rotenone samples (Fig. 1). Cove number one had a steep rocky shoreline whereas cove number two had a clay-silt-loam bottom with a gently sloping shoreline. Test netting and rotenone sampling were carried out in cooperation with the Kansas Fish and Game Commission.

Weight and total length of flathead catfish were measured to the nearest

Table 8. Frequency of occurrence and numerical analysis by month of stomach contents from flathead catfish in the 801–900 mm length group.

| Food items | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Crayfish | | | | | | | | | |
| Gizzard shad | | | | | | | | | |
| Unrecognizable fish | 1 (33)*<br>1 (100)** | | | | | | | | 1 (14)<br>1 (50) |
| Insects and larvae | | | | | | | | | |
| Channel catfish | | | | | | | | | |
| Drum | | | | | | | | | |
| Flathead catfish | | | | | | | | | |
| Green sunfish | | | 1 (100)<br>1 (100) | | | | | | 1 (14)<br>1 (50) |
| Carp | | | | | | | | | |
| Plant tissue | | | | | | | | | |
| Unrecognizable tissue | 2 (67)<br>— | 2 (100)<br>— | | 1 (100)<br>— | | | | | 5 (71)<br>— |
| Total no. of stomachs containing food | 3 | 2 | 1 | 1 | | | | | 7 |
| Total no. of organisms in stomachs | 1 | — | 1 | — | | | | | 2 |

* Frequency of occurrence.
** Numerical analysis.
( ) Percentage frequency of occurrence or percentage numerical analysis, rounded to nearest whole percent.

gram and millimeter respectively, and spines were removed and sectioned for age and growth determination (Layher and Boles, 1979). Then each fish was eviscerated. The esophagus and duodenum were tied tightly with nylon cord to retain stomach contents. Stomachs were removed by cutting posterior to the duodenum ties and anterior to the esophagus ties, injected with 10 percent formalin, and placed in a 10 percent formalin solution. Stomachs were extracted from 172 of 200 flathead catfish collected. The 172 stomachs do not include those from fish taken by rotenone poisoning. Stomach contents were analyzed by length and age of the flathead catfish, numbers of food items, frequency of occurrence and month.

## Results and Discussion

The months of May, July and August were the most productive. In May, fish were easily taken by trotline in the timbered area at the upper end of the reservoir. In July and August they were easily caught by rod and reel

Table 9. Frequency of occurrence and numerical analysis by month of stomach contents from flathead catfish in the 901–1000 mm length group.

| Food items | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Crayfish | | | | | | | | | |
| Gizzard shad | | 1 (17)* | | | | 2 (67) | | | 3 (33) |
| | | 1 (25)** | | | | 2 (67) | | | 3 (43) |
| Unrecognizable fish | | | | | | 1 (33) | | | 1 (11) |
| | | | | | | 1 (33) | | | 1 (14) |
| Insects and larvae | | | | | | | | | |
| Channel catfish | | | | | | | | | |
| Drum | | 3 (50) | | | | | | | 3 (33) |
| | | 3 (75) | | | | | | | 3 (43) |
| Flathead catfish | | | | | | | | | |
| Green sunfish | | | | | | | | | |
| Carp | | | | | | | | | |
| Plant tissue | | | | | | | | | |
| Unrecognizable tissue | | 2 (50) | | | | | | | 2 (22) |
| | | — | | | | | | | — |
| Total no. of stomachs containing food | | 6 | | | | 3 | | | 9 |
| Total no. of organisms in stomachs | | 4 | | | | 3 | | | 7 |

* Frequency of occurrence.
** Numerical analysis.
( ) Percentage frequency of occurrence or percentage numerical analysis, rounded to nearest whole percent.

next to the causeway by using artificial lures as bait. The ease with which they were taken along the causeway was probably because the fish spawn in the rocky rip-rap covering the causeway (Layher and Boles, 1979). After spawning, feeding activity may increase.

Another attractant to the rip-rap may be the large numbers of small gizzard shad which "graze" on filamentous algae attached to the large rocks. As the rip-rap is composed of boulder sized rocks, adequate spaces for flathead hiding places exist. The gizzard shad are extremely susceptible to flatheads lying in wait. The constant success of the author angling for flatheads by retrieving artificial lures resembling the gizzard shad and crayfish strengthens this idea. Filamentous algae does not exist on the rip-rap until late June and angling success for flatheads prior to this time along the causeway is almost nonexistent.

Gizzard shad of small size appear in flatheads of all length classes (Table

Table 10. Frequency of occurrence and numerical analysis by month of stomach contents from flathead catfish in the 1001–1100 mm length group.

| Food items | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Crayfish | | | | | | | | | |
| Gizzard shad | | | | | | | | | |
| Unrecognizable fish | | 1 (50)* | 1 (100) | | | | | | 2 (50) |
| | | 1 (100)** | 1 (100) | | | | | | 2 (100) |
| 2 (50) | | | | | | | | | |
| 2 (100) | | | | | | | | | |
| Insects and larvae | | | | | | | | | |
| Channel catfish | | | | | | | | | |
| Drum | | | | | | | | | |
| Flathead catfish | | | | | | | | | |
| Green sunfish | | | | | | | | | |
| Carp | | | | | | | | | |
| Plant tissue | | | | | | | | | |
| Unrecognizable tissue | 1 (100) | 1 (50) | | | | | | | 2 (50) |
| | — | — | | | | | | | — |
| Total no. of stomachs containing food | 1 | 2 | 1 | | | | | | 4 |
| Total no. of organisms in stomachs | — | 1 | 1 | | | | | | 2 |

* Frequency of occurrence.
** Numerical analysis.
( ) Percentage frequency of occurrence or percentage numerical analysis, rounded to nearest whole percent.

1). Brown and Dendy (1961) found that the types of fishes utilized by the predator as forage were related to the size of the predator. In this study there were no positive data to support this assumption, although a tendency toward this type of feeding may have been present (Table 2).

Flathead catfish under 300 mm were not collected except by rotenone. Twelve fish under 300 mm in length collected by rotenone were found to be gorged with small forage fishes (all gizzard shad), apparently associated with the early effects of the toxicant on the smaller fishes present. While this piscivorous behavior of small flatheads was of an unnatural occurrence, it may suggest that reservoir populations of flatheads begin utilizing fish as a food source earlier than flatheads from riverine environments.

Flathead catfish from 300 mm to 500 mm were found to rely on both benthic macroinvertebrates (crayfish) as well as fish (Tables 3–4). The only fish species found in these predators of this size were gizzard shad. One

Table 11. Frequency of occurrence and numerical analysis by month of stomach contents from 172 flathead catfish.

| Food items | Apr. | May | June | July | Aug. | Sept. | Oct. | Nov. | Totals |
|---|---|---|---|---|---|---|---|---|---|
| Crayfish | | | 2 (14)* | 10 (29) | 11 (19) | | | | 23 (15) |
| | | | 2 (15)** | 11 (31) | 12 (17) | | | | 25 (18) |
| Gizzard shad | 1 (14) | 3 (14) | 6 (43) | 10 (29) | 26 (45) | 3 (50) | 2 (50) | 3 (43) | 54 (36) |
| | 2 (67) | 4 (33) | 8 (62) | 21 (58) | 49 (71) | 5 (83) | 3 (75) | 8 (89) | 100 (66) |
| Unrecognizable fish | 1 (14) | 2 (09) | 2 (14) | 1 (03) | 6 (10) | 1 (17) | 1 (25) | 1 (14) | 15 (10) |
| | 1 (33) | 2 (17) | 2 (15) | 1 (03) | 7 (10) | 1 (17) | 1 (25) | 1 (11) | 16 (11) |
| Insects and larvae | | | | 2 (06) | | | | | 2 (01) |
| | | | | 3 (08) | | | | | 3 (02) |
| Channel catfish | | | | | 1 (02) | | | | 1 (01) |
| | | | | | 1 (01) | | | | 1 (01) |
| Drum | | 4 (18) | | | | | | | 4 (03) |
| | | 4 (33) | | | | | | | 4 (03) |
| Flathead catfish | | 1 (05) | | | | | | | 1 (01) |
| | | 1 (08) | | | | | | | 1 (01) |
| Green sunfish | | | 1 (07) | | | | | | 1 (01) |
| | | | 1 (08) | | | | | | 1 (01) |
| Carp | | 1 (05) | | | | | | | 1 (01) |
| | | 1 (08) | | | | | | | 1 (01) |
| Plant tissue | | 2 (09) | | | 3 (05) | | | | 5 (03) |
| | | — | | | — | | | | — |
| Unrecognizable tissue | 5 (07) | 9 (41) | 3 (21) | 11 (32) | 11 (19) | 2 (33) | 1 (25) | 3 (43) | 45 (30) |
| | — | — | — | — | — | — | — | — | — |
| Total no. of stomachs containing food | 7 | 22 | 14 | 34 | 58 | 6 | 4 | 7 | 152 |
| Total no. of organisms in stomachs | 3 | 12 | 13 | 36 | 69 | 6 | 4 | 9 | 152 |

* Frequency of occurrence.
** Numerical analysis.
( ) Percentage frequency of occurrence or percentage numerical analysis, rounded to nearest whole percent.

crayfish was found in a stomach from a flathead in the 500 to 600 mm length group (Table 4) but none were found in flatheads of larger size (Tables 6–10). Crayfish were never found in flatheads age VII or older.

The disappearance of crayfish from the diet of larger flatheads may be due to exclusion of the larger predators from habitat where crayfish are found. As most flatheads in this study were collected near the causeway it

may be assumed that this structure was the primary type of habitat used by the population of flatheads sampled. The boulder sized rip-rap provides excellent resting, spawning and feeding sites for flatheads. Apparently small flatheads can inhabit small crevices and hence the more posterior portions of larger crevices than can larger flathead catfish. These areas would be more closely associated with the substrate of the large landfill and support the resident crayfish population. It is interesting to note that all crayfish examined were of one species, *Orconectes nais*.

Flathead catfish larger than 600 mm or over age VI were found to be exclusively piscivorous. The only fishes used as food sources other than gizzard shad were four freshwater drum, one channel catfish (*Ictalurus punctatus*), one flathead catfish, and one carp (*Cyprinus carpio*). These fish were all removed from flathead catfish collected in May (Table 11). It appears that after gizzard shad spawn in Milford Reservoir the flatheads of larger size utilize them almost exclusively for forage. This is probably an opportunistic phenomenon rather than one of selectivity. In one cove, which was sampled by means of an application of rotenone (cove no. 1 on Fig. 1), 98.9 percent (71,460 actual count) of the fishes collected were gizzard shad. This accounted for almost 90 percent of the biomass represented by fishes. However, it must be realized that cove rotenoning was done in July and comparisons between flathead diets for other months and this rotenone sample should not be made. Even when looking at the July stomach analysis of flatheads and subsequent examination of rotenone data it should be realized that the coves rotenoned did not furnish flatheads used in stomach analysis.

The effectiveness of predation by flathead catfish in controlling rough fish populations appears to be minimal in the presence of large numbers of available forage fishes such as gizzard shad. It is also noteworthy that all members of the gizzard shad population are not available or susceptible to predation by flathead catfish. Only those which "graze" on the algae attached to the rip-rap are available to flatheads residing in the rip-rap habitat. Also of interest is the fact that many relatively small drum, white crappie (*Pomoxis annularis*), and channel catfish were collected by angling in the same manner used to collect flathead catfish; however, these species never occurred in stomachs of flatheads taken from the rip-rapped area.

It would appear that forage is not a limiting factor to the flathead catfish population in Milford Reservoir, but suitable sites for foraging by flatheads may be limiting. This may explain why Marzolf (1955) found decreasing increments of growth at any given annulus formation with each older age group examined and Layher and Boles (1979) did not. As young flatheads mature they may find suitable habitat preoccupied and consequently exhibit slower growth than other members of the population which were established when the reservoir was first filled. Thus small gizzard shad may not be

available to younger flatheads in the numbers that they are available to the older flatheads catfish established in the rip-rapped landfill.

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## LITERATURE CITED

Brown, B. E., and J. S. Dendy. 1961. Observations on the food habits of the flathead and blue catfish in Alabama. Proc. S.E. Assoc. Game and Fish Comm. 15:210–222.

Clemons, H. P. 1954. Pre-impoundment studies of the summer food of three species of fishes in Tenkiller and Fort Gibson reservoirs, Oklahoma. Proc. Okla. Acad. Sci. 33:72–79.

Cross, F. B. 1967. Handbook of fishes of Kansas. Univ. Kan. Mus. Nat. Hist., Misc. Publ. 45. 357 pp.

Deacon, J. E. 1961. Fish populations following a drought in the Neosho and Marias des Cygnes rivers of Kansas. Univ. Kan. Publ., Mus. Nat. Hist. 13:359–427.

Environmental Protection Agency. 1977. Report on Milford Reservoir, Clay and Geary counties, Kansas. EPA Region VII, Working Paper No. 519. 14 pp.

Jones, L., and V. Ebert. 1977. Lower Republican River Basin, Kansas, Preliminary Stream Survey. Dingell-Johnson Project F-15-R-12, Study 010., Job .010. Kansas Forestry, Fish and Game Commission. 24 pp.

Langemeier, R. N. 1965. Effects of channelization on the limnology of the Missouri River, Nebraska, with emphasis on food habits and growth of the flathead catfish. M.A. Thesis. Univ. of Missouri, Columbia. 134 pp.

Layher, W. G., and Robert J. Boles. 1979. Growth of *Pylodictis olivaris* (Rafinesque) in a Kansas reservoir. Trans. Kan. Acad. Sci. 82(1):36–48.

Layher, W. G., K. Brunsen, and R. Standage. 1978. Assesment of the aquatic environment in Kansas. Report TR-11.1. Kansas Dept. of Health and Environment, Topeka, Kansas. 414 pp.

Marzolf, R. C. 1955. Use of pectoral spines and vertebrae for determining age and rate of growth of the channel catfish. Jour. Wildlife Mgmt. 19:243–249.

McCoy, H. A. 1953. The rate of growth of flathead catfish in twenty-one Oklahoma lakes. Proc. Okla. Acad. Sci. 34:47–52.

Minckley, W. L., and J. E. Deacon. 1959. Biology of the flathead catfish in Kansas. Trans. Amer. Fish. Soc. 88:344–355.

Swingle, H. S. 1954. Fish populations in Alabama rivers and impoundments. Trans. Amer. Fish. Soc. 83:48–57.

Swingle, H. S. 1967. Experiments with the flathead catfish (*Pylodictis olivaris*) in ponds. Proc. S.E. Assoc. Game and Fish Comm. 18:303–308.

Turner, P. K., and R. C. Summerfelt. 1970. Food habits of adult flathead catfish, *Pylodictis olivaris* (Rafinesque), in Oklahoma reservoirs. Proc. S.E. Assoc. Game and Fish Comm. 24:387–401.

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# Pleistocene Musk Oxen from Kansas

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ABSTRACT

Nine musk oxen specimens representing the genera *Symbos*, *Soergelia*, and *Euceratherium* are reported from Kansas. The late Pleistocene (Wisconsin) specimens of *Symbos* and *Euceratherium* were collected from gravel bars in the Kansas River near Kansas City and from terrace deposits along major drainages in western Kansas. The single specimen of *Soergelia* was collected from early Pleistocene (Kansan) sediments exposed along an irrigation canal in northcentral Kansas.

Fossil musk oxen have been known from Kansas for over a century. On April 3, 1877 Professor E. D. Cope of Philadelphia received the following letter:

Wilson, Kansas
Apr 3rd 77

Prof E. D. Cope
Dear Sir
We arrived hear last night. I found a skull of some extinct animal which I purchased and sent to you today per express & which I did not have the money to pay for it so please send it to Mr. Jacob Fowler. He would like to know what it is & the price is $2. Please send it at your earliest convenience.

Yours truly,
[Signed]
Charles H. Sternberg

Cope identified the skull as *Scaphoceros* sp. indet. However, Brown (1908) later changed the identification to *Symbos* sp. indet.; the genus having been erected by Osgood (1905) to replace *Scaphoceros* Osgood, preoccupied.

Occurrences of fossil musk oxen collected in Kansas over the last 100 years have received only scattered notices (Hay, 1923; Hibbard, 1943; Lane, 1948). However, the recent discovery of two partial musk oxen skulls and a single maxilla from the Kansas River near Kansas City has prompted us to document all known specimens of this interesting ovibovid from Kansas.

Museum and institutional abbreviations are:

AMNH—American Museum of Natural History
FHSM—Fort Hays State University, Sternberg Memorial Museum
KUVP—Kansas University Vertebrate Paleontology
UM—University of Michigan, Museum of Paleontology

## Musk Oxen in Kansas

Nelson and Madsen (1978) recognized five genera of fossil musk oxen from North America: *Ovibos, Symbos, Bootherium, Praeovibos* and *Soergelia*. They generally followed Hibbard (1955) and Simpson (1963) in omitting *Euceratherium*. Hibbard placed *Euceratherium* in the new tribe Euceratherini of the subfamily Caprinae, while Simpson states, "The group [Euceratheres] as a whole is of doubtful position within the Bovidae." However, Harington (1979, written communication) called our attention to the general musk oxen-like morphology and the solid horn cores of *Euceratherium*, the latter a seemingly diagnostic feature of the Tribe Ovibovini. Therefore, we also recognize *Euceratherium* as a musk oxen.

Of the 6 musk oxen genera known from North America, only three genera are reported from Kansas. The Helmeted Musk Oxen, *Symbos cavifrons* (Leidy) (Fig. 1) is known from three occurrences along the Kansas River in Wyandotte County and from four locations in west-central Kansas. *Symbos* is a rather widespread form having been recorded from several localities in Canada and in Alaska, Arkansas, California, Colorado, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Missouri, Nebraska, New Mexico, North Dakota, Ohio, Oklahoma, Utah, Virginia, Washington, Wisconsin, and from the continental shelf 65 km east of Atlantic City, New Jersey.

Soergel's Musk Oxen, *Soergelia*, is known in Kansas by a single specimen collected from an irrigation canal in Jewel County (Eshelman, 1980, written communication). This lowland musk oxen is rarely encountered in North America and is known from three localities: the Jewel County, Kansas locality, Texas and the Old Crow Basin in the Yukon Territory of northwestern Canada (Harington, 1978, written communication).

Another lowland musk oxen, *Praeovibos*, is evidently restricted to the northern part of North America. Harington (1978, written communication) has recorded the occurrence of several individuals from the Yukon; however, there is no evidence that *Praeovibos* reached as far south as the contiguous United States.

The extant Tundra Musk Oxen, *Ovibos moschatus* (Zimmerman) (Fig. 1), is well known from Pleistocene and Holocene deposits in northern and central North America. *Ovibos* evidently ranged as far south as Red Willow County, Nebraska, just north of the Kansas border.

The most perplexing musk oxen to work with are the half dozen species that have been identified as *Bootherium*: *B. nivicolens*, *B. sargenti*, *B. bombifrons*, *B. appalachicolus*, *B. brazosis* and *Bootherium* sp. indet. (Fig. 2). The taxonomic status of this enigmatic ovibovid is still uncertain at present. Some workers have indicated that *Bootherium* represents a female *Symbos* (see summaries in Semken, Miller and Stevens, 1964; and Nelson and Madsen, 1978). Nelson and Madsen concluded that ". . . *Bootherium bombifrons* represents a genus distinct from *Symbos*. The status of *B. sargenti* and *B. appalachicolus*, however, remains in question." They also agreed with the observation of Ray (Ray, Cooper and Benninghoff, 1967) that "only a generic determination seems warranted pending further studies."

In North America widely scattered occurrences of *Bootherium* have been reported from Alaska and the Yukon south to Douglas County, Nebraska; *Bootherium* is not known from Kansas.

Most specimens of *Euceratherium* (Fig. 2) are recognized from the late Pleistocene deposits of western North America, particularly California. However, other occurrences of shrub oxen are reported from Mexico northward to Oregon and eastward to Cumberland Cave in Maryland (Martin and Guilday, 1967). As with *Symbos* and *Bootherium*, there is confusion in the possible role of sexual dimorphism in *Euceratherium*. Stock and Furlong (1927) suggested that *Euceratherium* and *Preptoceras* were sexually dimorphic forms. Simpson (1963) also recognized this possibility when he stated that, "The occurrence in a single deposit of two separate species of such closely similar herbivores [*Euceratherium* and *Preptoceras*] of almost exactly the same size would be extremely unusual."

## Measurement of Specimens

All cranial material was measured in the manner described by Nelson and Madsen (1978) for musk oxen and Skinner and Kaisen (1947) for *Bison*. A summary for all measured specimens is given in Tables 1 and 2.

## Annotated List

1. *Symbos* cf. *cavifrons*. AMNH 12669.

The American Museum of Natural History is the repository for the skull sent to Cope by C. H. Sternberg in 1877. This specimen was later described by Allen (1913), who referred it to *Ovibos*, Brown (1908), who correctly identified it as *Symbos*, and Hay (1923) and Lane (1948). The skull is badly damaged and only the occipital and basicranial regions are intact. Both horn

Fig. 1. Artist's conception of (A) *Symbos cavifrons* and (B) *Ovibos moschatus*.

Fig. 2. Artist's conception of (A) *Euceratherium* sp. and (B) *Bootherium* sp.

cores are missing and the sinuses below the horn cores are exposed (Manning, 1979, written communication). Hay (1923) noted that the skull was ". . . a rather large one. The distance across the constriction of the occiput, below the horn cores is 135 mm; that across the mastoid bones, 205 mm."

No other information is available about the discovery of this specimen except that it was found near Wilson, Kansas. Apparently it was collected from late Pleistocene (Wisconsin) sediments along the Smoky Hill River.

2. *Symbos cavifrons*. KUVP 54004.

In May of 1977 one of us (Neas) collected a partial skull of *Symbos cavifrons* from the north bank of the Kansas River in the NW¼, SE¼, Sec. 29, T. 11 S., R. 24 E., Wyandotte County, Kansas. The specimen, free of enclosing sediments, was found in about one foot of water during a low stage of the river.

The skull consists of the proximal two-thirds of each horn core, and the orbital, occipital, and basicranial regions. Brown in color and moderately waterworn, the skull lacks the facial region and maxillae.

Measurements of the Kansas River skull compare favorably with other specimens of *Symbos* from the state (Table 1). However, the specimen has a relatively broad exostosis in relation to the basal breadth of the horn core. This variation, found in both the Kansas specimens and others reported in the literature, may indicate either sexual dimorphism or relative age.

Sand bars along the Kansas River have been good sources of Pleistocene mammalian remains. In addition to musk oxen, proboscideans (*Mammuthus* and *Mammut*), moose (*Cervalces*), bison (*Bison crassicornis* and *B. antiquus*), giant beaver (*Castoroides*), peccary (*Mylohyus*), and sloth (*Megalonyx jeffersoni*) have been recovered. Other finds, for which no definite Pleistocene age has been established, include: human (*Homo*), bear (*Ursus*), wolf (*Canis*), mountain lion (*Felis*), and elk (*Cervus*).

Although Pleistocene terraces have been mapped along the Kansas River from Lawrence to Bonner Springs, no stratigraphic study has been completed eastward to Kansas City. The Newman Terrace has been identified as occurring in Sec. 29, T. 11 S., R. 23 E., at Bonner Springs, about 6 miles upstream (mostly west) from the musk oxen locality (Dufford, 1958). Today this area is being subjected to rapid downcutting.

The soil survey of Leavenworth and Wyandotte counties, Kansas (Zavesky and Boatright, 1977) reports a discontinuous system of the same soil complex extending eastward from Bonner Springs toward Kansas City. This soil complex commonly correlates with mapped Newman Terrace deposits further west; therefore, it is reasonable to assume that the Newman Terrace occurs in the main valley of the Kansas River east of Bonner Springs. Frye and Leonard (1952) believed this low terrace rested below latest Wisconsin deposits but still was Wisconsin in age. Lillegraven (1966) reached a similar

Table 1. Measurement (mm) of crania of *Symbos cavifrons*.

| | | FHSM 1684 | FHSM 11547 | FHSM 8138 | KUVP 54004 | KUVP 58013 |
|---|---|---|---|---|---|---|
| Transverse diameter of horn core base | Left | 119 | 118 | 144 | 110 | 120± |
| | Right | – | 115± | 146 | 107 | – |
| Dorsoventral diameter of horn core base | Left | 72 | 77± | 103 | 78 | 85± |
| | Right | – | 78± | 91 | 78 | – |
| Circumference of horn core base | Left | 337 | 323± | 391 | 316 | – |
| | Right | – | 317 | 405 | 318 | – |
| Exostosis length | | – | 242± | 214 | 212 | 250± |
| Exostosis width (ant. to horn core) | | 96± | 102 | 70 | 101 | 114± |
| | | – | – | – | – | – |
| Basioccipital width | Posterior | – | – | – | 71 | 83 |
| | Medial | – | – | – | 67 | 72 |
| Width across occipital condyles | | – | – | – | 121 | 139 |
| | | – | – | – | – | – |
| Width of cranium behind horn cores | | 131± | 117± | 119 | 136 | 151± |
| | | – | – | – | – | – |
| From occipital crest to top of foramen magnum | | 154± | – | 167 | 153 | – |
| | | – | – | – | – | – |
| Foramen magnum | Vertical | – | – | 35 | 34 | 46 |
| | Horizontal | – | – | 43 | 47 | 45 |

conclusion when he stated that ". . . the specimen [*Bison crassicornis*] came from on or just below the Newman Terrace."

3. *Symbos cavifrons*. KUVP 54017.

In October of 1978, a partial maxilla of *Symbos cavifrons* was presented to the Museum of Natural History by Richard Rogers, then a graduate student at the University of Kansas. This specimen was collected from the same sand bar which earlier yielded the *Symbos* cranium (KUVP 54004). According to Mr. Rogers, the maxilla was found at the head of the bar, partially

Table 2. Measurements (mm) of the teeth of *Symbos cavifrons* (KUVP 54017).

| | Length | Breadth |
|---|---|---|
| Right $P^4$ | 23 | 20.5 |
| Right $M^1$ | 31 | – |
| Right $M^2$ | 34 | 24 |
| Right $M^3$ | 37 | 24 |
| Length of tooth series by alveoli | | 176 mm |
| Length of premolar row (along alveoli) | | 73 mm |
| Length of molar row (along alveoli) | | 107 mm |

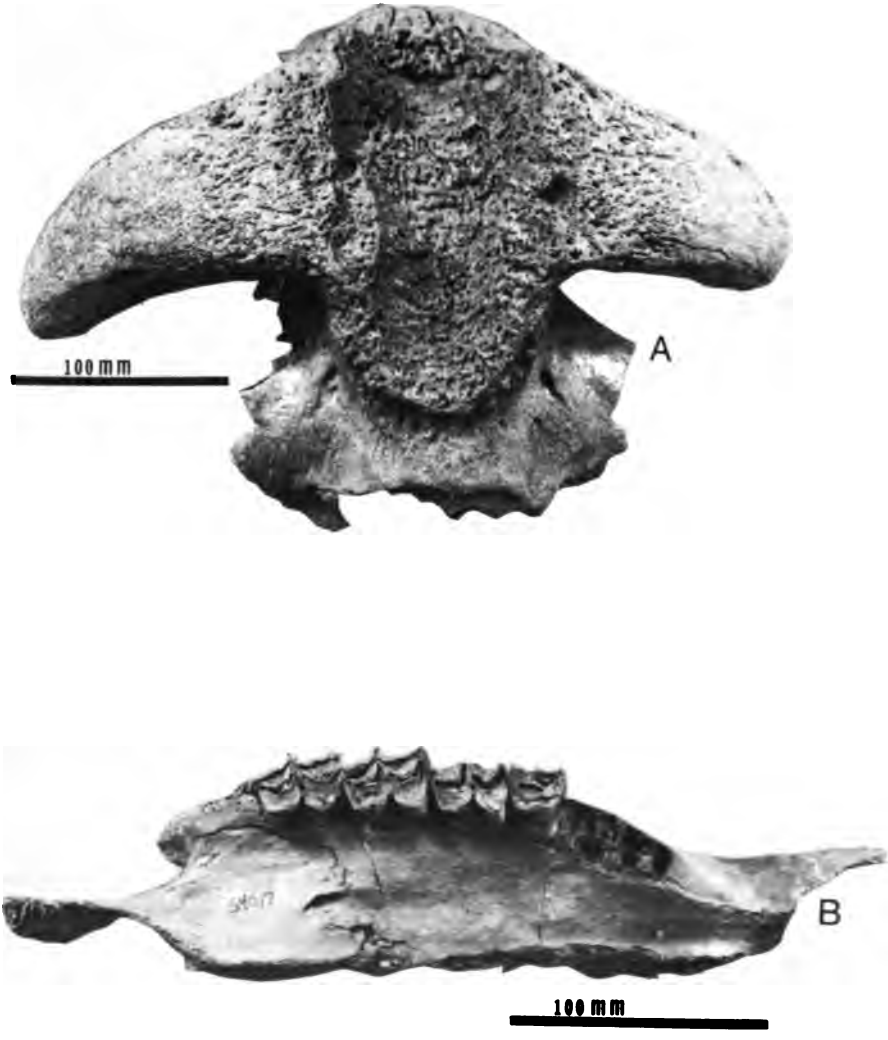


Fig. 3. *Symbos cavifrons*. (A) KUVP 54004. Dorsal view of cranium. (B) KUVP 54017. Partial maxilla with $P^4$–$M^3$ and alveoli for $P^2$ and $P^3$.

buried in gravel. A few meters downstream a bison skull (*Bison bison*) was recovered and about 700 meters farther downstream a human femur (*Homo sapiens*), and the jaw of a horse (*Equus* sp.) were found.

The maxillary section contains $P^4$–$M^3$ with alveoli for $P^2$ and $P^3$. The labial surface of $M^1$ is absent and the teeth show moderate wear. The teeth are assignable to *Symbos*, differing from *Bison* in lacking accessory lingual

Fig. 4. *Symbos cavifrons*. (A) KUVP 58013. Left lateral view of partial cranium and horn core. (B) FHSM 1694. Dorsal view of cranium.

Fig. 5. *Symbos cavifrons*. (A) FHSM 8138. Dorsal view of cranium. (B) FHSM 11545. Dorsal view of cranium.

cusps on the inner angles of the molars, and from *Ovibos* in lacking anterior depressions in the teeth for the posterior loop of the preceding tooth (Allen, 1913; Semken, 1964).

The occurrence of the maxilla and the cranium in the same sand bar, together with the rarity of musk oxen remains in Kansas, strongly suggests the possibility that they represent the same individual. However, since the other interconnecting elements of the skull are missing, they must be regarded as separate occurrences.

4. *Symbos cavifrons*. KUVP 58013.

The most recent specimen of *Symbos cavifrons* found in Kansas was collected September 16, 1979 by students of the University of Kansas Museum of Natural History, Ichthyology Division. While routinely sampling the Kansas River fish fauna, David Wiseman and Owen Gorman discovered a well preserved cranium (KUVP 58013) lying near the middle of the river channel in the NW¼, Sec. 5, T. 12 S., R. 23 E., Wyandotte County. The skull was found inverted, covered with silt and water, along a gravel bar inlet. As for the other Kansas River fossils, stratigraphic control is lacking.

The skull consists of an intact braincase, a complete, but posterodorsally damaged, left horn core, the basal one-third of the right horn core, the frontal portions of both orbits, and abraded exostosis. This specimen entirely lacks the muzzle region and both maxillae. The complete left horn core, approximately 40 cm in length, exemplifies the long, downward and forwardly directed horns of *Symbos*. Measurements of the specimen (Table 1) identify it as the largest known individual of *Symbos cavifrons* from the state of Kansas and as such it may represent a male.

5. *Symbos cavifrons*. FHSM 1694.

A badly damaged incomplete musk oxen cranium was presented to the Sternberg Memorial Museum sometime before 1927. The skull consists of the braincase and approximately one-fifth of the left horn core. The occipital region is badly damaged and the cranial cavity is exposed on the left side. The skull appears to have been transported a considerable distance by stream activity.

No locality information was recorded for the skull; however, it probably was collected in western Kansas.

6. *Symbos cavifrons*. FHSM 8138.

This record is based upon the posterior part of a cranium collected south of Coldwater, Kansas. The right horn core is broken off near the base; approximately one-fifth of the left horn core is still intact. The skull does not appear to have been transported a great distance as the rugosities in the

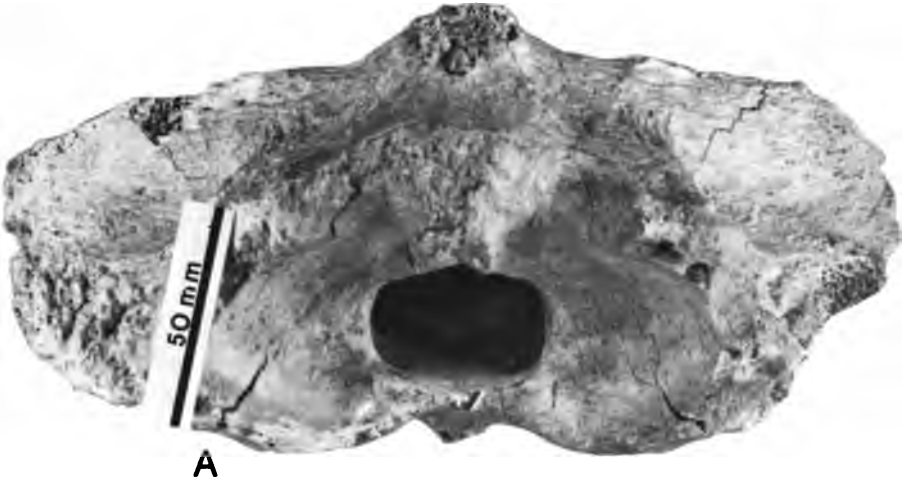

Fig. 6. *Symbos cavifrons*. (A) FHSM 11547. Atlas. (B) FHSM 11546. Axis.

exostosis are still well defined. The exostosis is extremely wide (Table 1) and very well developed; this indicates that this skull may be of a mature animal.

The specimen was collected 12 miles south of Coldwater, Kansas in 1966 by Howard Hadley. The collection site is in either the NW¼, NW¼, T. 34 S., R. 18 W. or the NE¼, NE¼, T. 34 S., R. 19 W. from late Pleistocene sediments exposed along the Salt Fork of the Arkansas River.

7. *Symbos cavifrons*. FHSM 11545, 11546, and 11547.

In 1966 Darrel Ruder presented a partial cranium and a nearly complete axis and atlas to the Sternberg Memorial Museum. The fossils were collected from a sand and gravel quarry three miles south and three miles east of Gorham, Kansas in the SW¼, T. 14 S., R. 15 W. from late Pleistocene rocks exposed along a tributary to Big Creek.

The cranium is badly fragmented and is represented only by the exostosis and the proximal one-fifth of the right horn core. However, the specimen is diagnostic enough to allow assignment to *Symbos cavifrons*.

The atlas and axis exhibit all of the characteristics of cervical vertebrae typical of *Symbos*—ponderous construction, constricted neural canal, and a rugose sculpture (Ray, Cooper and Benninghoff, 1967).

8. *Soergelia* cf. *mayfieldi*.

In 1973 R. E. Eshelman, then of the University of Michigan, collected a partial cranium of *Soergelia* cf. *mayfieldi* from a late Kansan deposit in Jewel County, Kansas in the SE¼, Sec. 8, T. 1 S., R. 6 W. (Eshelman, 1980, written communication). The specimen consists of the posterior part of the cranium, one-half of the left horn core, most of the right horn core, and most of the occipital region. The specimen is presently undescribed; however, C. R. Harington (1978, written communication) believes that it is the most complete cranium of *Soergelia* yet discovered. Harington further believes that *Soergelia* is probably diagnostic of the Kansan.

9. *Euceratherium* sp. KUVP 6686.

Evidently *Euceratherium* is represented in Kansas by an isolated third lower molar. Lane (1948) reports that the tooth ". . . was found by Dr. Thad McLaughlin of the United States Geological Survey in Grant County, Kansas. It came from the Sullivan pit in the SW¼ of Section 7, Township 29 South, Range 37 West, and is in the University of Kansas Museum." Although now missing, the specimen was figured by Hibbard (1943) who reported "the anteroposterior diameter of the tooth is 38.25 mm."

## Discussion

Nine specimens of musk oxen representing *Symbos cavifrons*, *Soergelia* cf. *mayfieldi* and *Euceratherium* sp. are now known from Kansas. Speci-

mens of *Symbos* and *Euceratherium* were collected from probable late Pleistocene (Wisconsin) fluvial sand and gravels. The single specimen of *Soergelia* was collected from early Pleistocene (Kansan) sands and is probably a diagnostic "index fossil" of the Kansan. Undoubtedly new specimens of *Symbos* will be found on sand bars in the Kansas River near Kansas City, and we suggest the source of these fossils may be correlated with outcrops of the Newman Terrace.

## Acknowledgments

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We also owe a special thanks to the following individuals who had the foresight to save these specimens and make them available for scientific study: Howard Hadley, Richard Rogers, Darrel Ruder, David Wiseman and Owen Gorman.

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## Literature Cited

Allen, J. A. 1913. Ontogenetic and other variations in muskoxen, with a systematic review of the muskox group, recent and extinct. Mem. Amer. Mus. Hist., n.s. 1(4):101–226.

Brown, B. 1908. The Conard Fissure, a Pleistocene bone deposit in northern Arkansas: with descriptions of two new genera and twenty new species of mammals. Mem. Amer. Mus. Nat. Hist. 9(4):155–208.

Dufford, A. E. 1958. Quaternary geology and ground-water resources of Kansas River valley between Bonner Springs and Lawrence, Kansas. State Geol. Surv. Kans. Bull. 130(1): 1–96.

Frye, J. C., and A. B. Leonard. 1952. Pleistocene geology of Kansas. State Geol. Surv. Kans. Bull. 99:1–230.

Hay, O. P. 1923. The Pleistocene of North America and its vertebrated animals from the states east of the Mississippi River and from the Canadian provinces east of longitude 95°. Carnegie Inst. Wash. Pub. 322, 499 pages.

Hibbard, C. W. 1943. *Etadonomys*, a new Pleistocene heteromyid rodent, and notes on other Kansas mammals. Trans. Kans. Acad. Sci. 46:185–191.

Hibbard, C. W. 1955. Pleistocene vertebrates from the upper Becerra (Becerra Superior) Formation, Valley of Tequixquiac, Mexico, with notes on other Pleistocene forms. Univ. Mich. Mus. Pal. Contrib. 12(5):47–96.

Lane, H. H. 1948. A survey of the fossil vertebrates of Kansas. Part 5, Mammalia. Trans. Kans. Acad. Sci. 5(1):29–76.

Lillegraven, J. A. 1966. *Bison crassicornis* and the ground sloth *Megalonyx jeffersoni* in the Kansas Pleistocene. Trans. Kans. Acad. Sci. 69(3–4):294–300.

Martin, P. S., and J. E. Guilday. 1967. A bestiary for Pleistocene biologists. In Martin, P. S., and H. E. Wright, editors, Pleistocene extinctions. The search for a cause. Yale Univ. Press, New Haven, Conn., 453 pages.

Nelson, M. E., and J. H. Madsen. 1978. Late Pleistocene musk oxen from Utah. Trans. Kans. Acad. Sci. 81(4):277–295.

Osgood, W. H. 1905. *Symbos*, a substitute for *Scaphoceras*. Proc. Biol. Soc. Wash. 18:223.

Ray, C. E., B. N. Cooper, and W. S. Benninghoff. 1967. Fossil mammals and pollen in a late Pleistocene deposit at Saltville, Virginia. Jour. Paleo. 41(3):608–622.

Semken, H. A., B. B. Miller, and J. B. Stevens. 1964. Late Wisconsin woodland musk oxen in association with pollen and invertebrates from Michigan. Jour. Paleo. 38(5):823–835.

Simpson, G. G. 1963. A new record of *Euceratherium* or *Preptoceras* (extinct Bovidae) in New Mexico. Jour. Mamm. 44:583–584.

Skinner, M. F., and O. C. Kaisen. 1947. The fossil bison of Alaska and preliminary revisions of the genus. Bull. Amer. Mus. Nat. Hist. 89(3):123–256.

Stock, C., and E. L. Furlong. 1927. Skull and skeletal remains of a ruminant of the *Preptoceras-Euceratherium* group from the McKittrick Pleistocene, California. Cal. Univ. Dept. Geol. Sci. 16(10):409–427.

Zavesky, L. D., and W. C. Boatright. 1977. Soil survey of Leavenworth and Wyandotte counties, Kansas. USDA, Soil Conservation Service, 80 pages.

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# Strike-Induced Chemosensory Searching in Rattlesnakes (*Crotalus enyo*) as a Function of Disturbance Prior to Presentation of Prey

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## ABSTRACT

Rattlesnakes *(Crotalus enyo)* exhibited higher rates of tongue flicking after striking and envenomating a mouse than after seeing, smelling, or detecting the warmth of a mouse. Thus, chemosensory searching subserved by the vomeronasal system is activated consequent to the delivery of a successful predatory strike. Furthermore, this effect was observed even when the rattlesnakes were disturbed (by handling or transportation to a new environment) just prior to being exposed to mice. Hence, activation of chemosensory searching by a predatory strike appears to be an unconditional or obligate response in *C. enyo*; at the very least we conclude that the response is unaltered by defensive reactions induced by handling. This, in turn, suggests that predatory behavior in *C. enyo* is a closed response chain such that release of the first element (striking) strongly predisposes the snake to engage in the next element (chemosensory searching) which brings the snake into contact with its dead prey so that cues arising from it can release swallowing. Once the chain is activated it goes to completion, and the only "choice point" is at the first step (i.e., the snake may "decide"

whether or not to strike a mouse, but once a strike has been made the snake appears to be obligated to execute the rest of the chain).

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Striking a mouse induces chemosensory searching (i.e., a sustained high rate of tongue flicking) in rattlesnakes (Chiszar, Radcliffe, and Scudder, 1977; Chiszar, Radcliffe, and Smith, 1978: Dullemeijer, 1961). Certain characteristics of this searching behavior suggest that it is a modal action pattern (Barlow, 1968, 1977). For example, once activated by striking, the rate of tongue flicking accelerates to an asymptotic level and then continues at this level for at least 30 min. Introduction of various odoriferous substances into the post-strike environment has little or no effect on the rate of tongue flicking (Chiszar, Radcliffe, and Scudder, 1977), suggesting that chemosensory searching proceeds at full intensity regardless of the type of odor present. Hence, this behavior appears to have two important properties in common with modal action patterns: (1) relative stereotypy, and (2) independence of sensory feedback (except for taxic effects). If the snake encounters a dead mouse during chemosensory searching, then cues arising from the carcass release swallowing. The entire feeding episode appears to be a response chain in which execution of each behavioral component places the predator in a position to perceive the stimuli which release the next component in the sequence. That is, striking is released by visual and thermal aspects of prey, and striking in turn releases chemosensory searching which facilitates trailing the wounded prey.

An important question now arises concerning the manner in which striking influences the next component of the response chain: Is striking prey an unconditional releaser of chemosensory searching? If the answer is yes, then we may understand this aspect of rattlesnake predatory behavior in relatively simple stimulus-response terms; and, the overall behavioral sequence might be conceptualized as a closed response chain which runs to completion once it is initiated. On the other hand, if striking prey does not always lead to chemosensory searching, then we must recognize the possibility that this system is more complex than stimulus-response terminology would imply. We have already shown that especially defensive rattlesnakes *(C. durissus terrificus)* exhibited smaller (but statistically reliable) post-strike tongue-flick-rate increases than nondefensive conspecifics, indicating that striking did not cause the former to discontinue attending to threat-eliciting cues (Chiszar, Radcliffe, and Smith, under review). Instead, the post-strike period was characterized by a mixture of chemosensory searching and ritualized threat responses. Thus, striking prey may be an unconditional releaser of chemosensory searching, but it is not an unconditional

suppressor of other behaviors which can interfere with chemosensory searching.

The present study was designed to evaluate the occurrence of strike-induced chemosensory searching under several conditions involving disturbance (e.g., handling) of the predators. If the chemosensory consequences of striking remain detectable even under these circumstances, we can make strong conclusions about the robustness of the effect of striking prey and about the unconditionality of this effect.

## Methods and Materials

*Subjects and maintenance conditions.* Five specimens of *Crotalus enyo* were observed in this experiment; all were at least 3 yr old and had been in captivity since birth. Snakes were maintained individually in glass terraria (50 × 27.5 × 30 cm), kept at 26–28°C during the light period (0800–2200), and 22–24°C during the dark period. The animals had been used in several previous experiments involving presentation of chemical stimuli but no surgical or pharmacological manipulations. Accordingly, we consider these snakes to be typical of long-term captive rattlesnakes.

Prior to the observations made in this study the snakes had been fasted for two months as part of an experiment designed to measure behavioral effects of food deprivation (Chiszar, Radcliffe, Smith, and Bashinski, in preparation). Until the beginning of that study the animals had been provided with 1 or 2 live mice every other week.

*Procedure.* Each snake was observed in eight conditions. In four of these, the snake was exposed for 3 sec to a live mouse suspended via forceps just out of striking range. In condition A the snake had been undisturbed in its home cage prior to being presented with the mouse. In condition B the snake had just previously been removed from its cage with the aid of a reptile hook and then replaced. In conditions C and D the snake had just been placed into a new cage; in one case the cage was clean while in the other the new cage contained mouse odors. The remaining four conditions (E–H) were exactly like A–D except that the snakes were allowed to strike the mouse at the end of the 3-sec exposure. In all cases the mouse was removed at the end of the 3-sec period, and all tongue flicks emitted during the next 5 min were recorded with the aid of a hand-held counter. Comparison of tongue flick rates emitted in conditions A and E will quantify the effect of striking prey on chemosensory searching for undisturbed snakes. Conditions B and F will show the effect for snakes disturbed by handling just prior to being exposed to a mouse. The remaining two comparisons (C vs G and D vs H) will show the effects for snakes residing temporarily in new cages during the observations.

*Statistical analysis.* Since all snakes were observed in all conditions, this study conforms to a repeated-measures experimental design. Further-

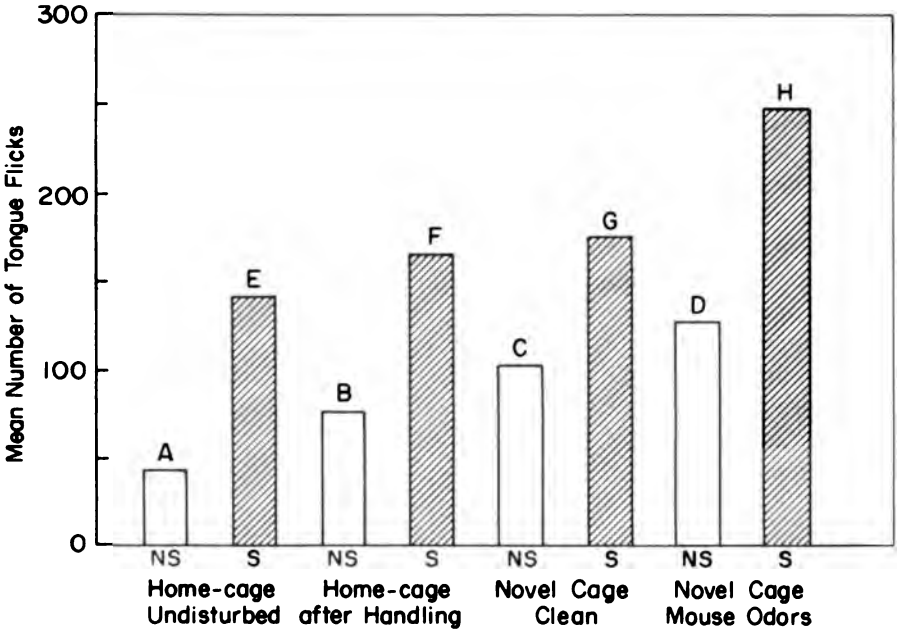


Fig. 1. Mean number of tongue flicks emitted by five *C. enyo* in each of eight 5 min tests. The open bars (A, B, C, and D) represent occasions when the snakes were exposed (3 sec) to a mouse but not given an opportunity to strike. The striped bars (E, F, G, and H) represent occasions when the snakes were allowed to strike a mouse. The magnitudes of the no-strike vs strike differences were statistically equal under each of the four conditions shown along the abscissa (see text for results of analysis of variance).

more, the design can be conceptualized as a 2 × 4 combination of presence vs absence of a strike with four observation conditions (home cage-undisturbed, home cage after brief handling, clean novel cage, novel cage containing mouse odors). Accordingly, data were subjected to a 2 × 4 repeated-measures analysis of variance. Specific paired comparisons were made using the method of orthogonal contrasts (Hicks, 1964).

## Results and Discussion

Mean numbers of tongue flicks emitted in each of the 5 min observation periods are shown in Figure 1. It is clear that strike-induced chemosensory searching occurred under all four observation conditions: Tongue flick rate after striking a mouse was consistently higher than after the no-strike presentations ($F = 103.24$, df = 1/4, $P < .01$). Comparison of tongue flick scores in conditions B, C, and D with those in condition A ($F = 9.67$, df = 1/12, $P < .05$) confirmed that disturbance elevated this measure. Yet, striking a mouse resulted in a proportionate increase such that a significant

strike-induced elevation of tongue flick rate occurred under each condition. Indeed, the interaction between presence vs absence of a strike and observation condition was insignificant in the ANOVA ($F = 1.21$, $df = 3/12$, $P > .05$). Accordingly, we conclude that disturbing these specimens of *C. enyo* prior to allowing them to strike a mouse did not interfere with the induction of chemosensory searching.

These results suggest that striking prey is an unconditional releaser of chemosensory searching. Yet, there are good reasons not to generalize this interpretation to all other crotalids. Specimens of *C. enyo* are among the calmest of all rattlesnakes we have maintained in captivity, most individuals being unlikely to strike or rattle even under provocation. Hence, they are not responsive to stimulation arising from keepers and equipment which would precipitate defensive behavior in other rattlesnakes. It is likely that handling and transportation to a novel environment would seriously interfere with predatory behavior in more defensive animals (Chiszar, Radcliffe, and Smith, in press). In spite of this qualification, it is interesting that striking has unconditional effects under the present circumstances. At least in *C. enyo* the activation of chemosensory searching appears to be simple process, dependent upon the action of striking and immune to the potentially disrupting influences of human presence, handling, transportation, or manipulation of odoriferous materials (see also Chiszar, Radcliffe, and Scudder, 1977).

## Literature Cited

Barlow, G. W. 1968. Ethological units of behavior. *In* D. Ingle (ed.), The central nervous system and fish behavior. Chicago: University of Chicago Press, 217–232.

Barlow, G. W. 1977. Modal action patterns. *In* T. Sebeok (ed.), How animals communicate. Bloomington, Indiana: Indiana University Press, 98–134.

Chiszar, D., C. W. Radcliffe, and K. M. Scudder. 1977. Analysis of the behavioral sequence emitted by rattlesnakes during feeding episodes. I. Striking and chemosensory searching. Behav. Biol. 21:418–425.

Chiszar, D., C. W. Radcliffe, and H. M. Smith. 1978. Chemosensory searching for wounded prey by rattlesnakes is released by striking: A replication report. Herp. Review 9:54–56.

Chiszar, D., C. W. Radcliffe, H. M. Smith, and H. Bashinski (in preparation). Effects of prolonged food deprivation on response to prey odors by rattlesnakes: A signal detection analysis.

Dullemeijer, P. 1961. Some remarks on the feeding behavior of rattlesnakes. Kon. Ned. Akad. Wetensch. Proc. Ser. C 64:383–396.

Hicks, C. R. 1964. Fundamental concepts in the design of experiments. New York: Holt, Rinehart and Winston.

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# Red Bobwhite from Douglas County, Kansas

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An erythristic juvenile female bobwhite (*Colinus virginianus*) was collected on 10 December 1978, by Vincent O'Neal approximately 6.5 km southeast of Lawrence, Douglas County, Kansas.

Its plumage was chocolate brown to chestnut throughout except for approximately 15 white feathers on the upper chest. Cole et al. (1949) described these white feathers as a "crop patch" which is always associated with the gene for red.

On the throat and crown were black, chocolate, and chestnut colored feathers. Some crown feathers exhibited wide black bands along the rachis, edged in chestnut. Black mottling with fine black vermiculation was evident on some belly and back feathers. Primaries and secondaries were solid gray to brownish gray, as were the rectuces. Primary coverts were brownish gray tipped with chestnut. The first and second toe of the right foot showed signs of partial albinism as did the second toe of the left foot. The legs and bill were black.

The Kansas specimen (KU 77115) is being held in the ornithological collections at The University of Kansas Museum of Natural History in Lawrence.

The bird weighed 190.5 grams, which compared favorably with weights of 18 juvenile bobwhites collected in December in Riley County, Kansas; these weighed an average of 195.9 grams (Robel and Linderman, 1966). Measurements of this specimen were: wing 108.7, tail 63.1, culmen 12.4 and tarsus 29.9; these are within the ranges noted by Aldrich (1946). Some of the specimens examined by Aldrich were from near Lawrence, Kansas.

The red quail was one of a covey of several birds, some displaying the erythristic phase and others normally colored. After the collection of this individual, O'Neal observed 3 to 4 of the red phase quail feeding with a covey of apparently normally colored birds.

On 19 December 1978, attempts were made to observe and collect additional specimens of the erythristic quail. Five coveys, ranging in size from 5 to 10 birds each, were located and six normally colored birds were collected. Three red phase birds were observed in the last covey. Additional attempts to obtain specimens proved unsuccessful.

No previous records of red bobwhites are known to exist for Kansas and accounts in the literature are rare. The earliest known description of a red bobwhite was by Gould (1842). Aldrich (1946) suggested Boston as the type locality for the specimen held in collection by Gould. As outlined by Cole et al. (1949), red bobwhites have been noted from Ohio in 1874, Virginia in 1921; and North Carolina in 1933.

Attempts at propagation of red bobwhites from the Ames Plantation in Tennessee resulted in considerable information being gathered on the color phase (Cole and North, 1931). Other specimens have been reported from Indiana in 1951 (Reeves, Bobwhite Quail Investigation, Ind. Dep. of Conserv., Div. Fish and Game Final Rept., P-R Project W-2-R, 1954, p. 35 *in* Rosene, The Bobwhite Quail; Its Life and Management, Rutgers Univ. Press, New Brunswick, N.J., 1969) and from Oklahoma in 1978 (Tyler, 1978). As far as is known the specimen from Oklahoma and the one reported here are the only individuals of the erythristic color phase of bobwhite reported from west of the Mississippi River.

Mr. Marvin Schwilling is gratefully acknowledged for his assistance, in preparation of the study skin and field survey for additional specimens.

## Literature Cited

Aldrich, J. W. 1946. The United States races of the bob-white. Auk 63:493–508.

Cole, L. J., H. L. Stoddard and E. V. Komarek. 1949. Red Bob-white—a report and correction. Auk 66:28–35.

——— and M. O. North. 1931. The red phase of the bobwhite, a sex-linked character. Wils. Bull. 43:83.

Gould, J. 1842. New species of the genus Ortyx. Proc. Zool. Soc. London. 10:182–183.

Reeves, M. C. 1954. Bobwhite quail investigation. Ind. Dep. of Conserv., Div. Fish and Game Final Rept., P-R Project W-2-R, p. 35 *in* Rosene, W. 1969. The Bobwhite Quail; Its Life and Management. Rutgers Univ. Press, New Brunswick, N.J.

Robel, R. J. and S. A. Linderman. 1966. Weight dynamics of unconfined bobwhite quail in Kansas. Trans. Kan. Acad. Sci. 69:132–138.

Tyler, J. D. 1978. Red bobwhites in Oklahoma. Wils. Bull. 90(4):653–655.

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# The Effects of Small Watershed Dams on Stream Flow

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Discussions about the effects of floodwater retarding dams or multipurpose structures on stream flow often include the premise that evaporative losses from the reservoirs detract from stream flow. This is not necessarily true. Although evaporation and consumptive uses of stored water are subtracted from total stream flow the net effect can be beneficial. Floodwater retarding dams enhance stream flow through storage of water as do natural pools along streams.

This paper presents reasoning in support of this conclusion. It can be argued that data do not exist to back it up. Such data would take years to collect in "before and after" programs. However, our observations, and those of watershed residents over the past 20 years, support our conclusion. We have seen no evidence to the contrary.

First, consider an *intermittent stream*. This is the case discussed most often. An intermittent stream flows due to one or both of two things—surface runoff and effluent groundwater. The groundwater table is always at or near the bed of an intermittent stream. During times of surface runoff the stream is feeding the aquifer. When surface runoff stops the aquifer feeds the stream until the water table drops below the streambed; then stream flow ceases.

Floodwater retarding dams and similar structures detain storm runoff and release it at a controlled rate. This prolongs stream flow after storms and increases the amount of water entering the aquifer. Seepage from the reservoir also enters the aquifer. These factors all act to prolong the flow of intermittent streams. After stream flow ceases seepage from the reservoir continues to enter the aquifer. Stream flow can begin again due to surface runoff from uncontrolled areas, seepage from the reservoir, or seepage from the aquifer. An intermittent stream does not require pipe flow from a reservoir to start stream flow below a dam.

Reservoir evaporation and consumptive uses are not pertinent to the analysis. Evaporation occurs, certainly. Consumptive uses are also commonly made. They do not, however, come at the expense of the base flow of the stream. They come from that portion of excess surface runoff which would have otherwise continued downstream during storms.

An *ephemeral stream* flows only due to surface runoff. The groundwater

table is always below its bed. Reservoirs store water which would otherwise have flowed away. The stored water may be "consumed" or evaporated; and some will seep into the ground. Water is usually present in stilling basins immediately below the dams. When surface runoff stops, stream flow ceases. There is no contribution to stream flow from the aquifer. When a rain comes, surface runoff from uncontrolled areas can cause stream flow below a dam without pipe flow from the reservoir.

Evaporative losses and consumptive uses, again, come from stored water which would otherwise have left the watershed. Ephemeral stream flow is enhanced by reservoirs, but not as much as is intermittent stream flow.

A *perennial stream* flows continuously because the water table is always above the streambed (except perhaps during extreme droughts). The aquifer is charged from the stream during surface runoff. Aquifer storage is adequate to sustain stream flow between periods of surface runoff. The effect of reservoirs is to prolong surface runoff and increase aquifer storage. The perennial nature of the stream is reinforced. Water which would otherwise have left the watershed is stored in reservoirs and is available for evaporation and consumption.

In each case some water is evaporated or perhaps used at the reservoir. This does decrease the total amount of water that can continue downstream, but the reduction comes from the excess runoff which otherwise would have flowed away during storms. So, as with natural pools in streams, storm runoff retained in reservoirs is available during dry periods and does enhance stream flow.

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# Nesting Habits of Diamondback Terrapins (*Malaclemys terrapin*) on the Atlantic Coast of Florida

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ABSTRACT

The reproductive habits of the Florida east coast terrapin, *Malaclemys terrapin tequesta* were studied from 1977 to 1979 at the Merritt Island National Wildlife Refuge, Brevard County, Florida. Nesting occurred only on dike roads, in contrast to other subspecies of *Malaclemys* which normally nest on sand dunes. Nesting occurred from April to July, during daylight hours, and reached a peak during periods of high air temperatures and clear skies. Mean clutch size was 6.7, and up to three clutches may be laid each year. The clutch size of *M. t. tequesta* is considerably smaller than that of northern populations of *Malaclemys*. Small clutch size is apparently correlated with an increase in egg and hatchling size, which may result in higher survivorship of offspring in southern populations.

The diamondback terrapin, *Malaclemys terrapin* is one of the most widely distributed species of turtles in North America, extending from Cape Cod southward to the Florida Keys, and as far west as the Gulf coast of Texas. Such a wide-ranging species might be expected to show considerable variation in its reproductive biology. Unfortunately, field studies of the reproductive habits of *Malaclemys* have been limited to the northern subspecies, *M. t. terrapin* (Finneran, 1948; Reid, 1955; Burger and Montevecchi, 1975; Montevecchi and Burger, 1975; Burger, 1976a,b, 1977). Information regarding reproduction in other subspecies is confined to captive specimens (Hildebrand, 1929, 1932; Burns and Williams, 1972); the usefulness of this information is limited (Carr, 1952; Burnley, 1969).

The Florida east coast terrapin, *M. t. tequesta* has the southernmost distribution of any *Malaclemys* with the exception of *M. t. rhizophorarum*. Recent papers have dealt with mortality (Seigel, 1978), predation (Seigel,

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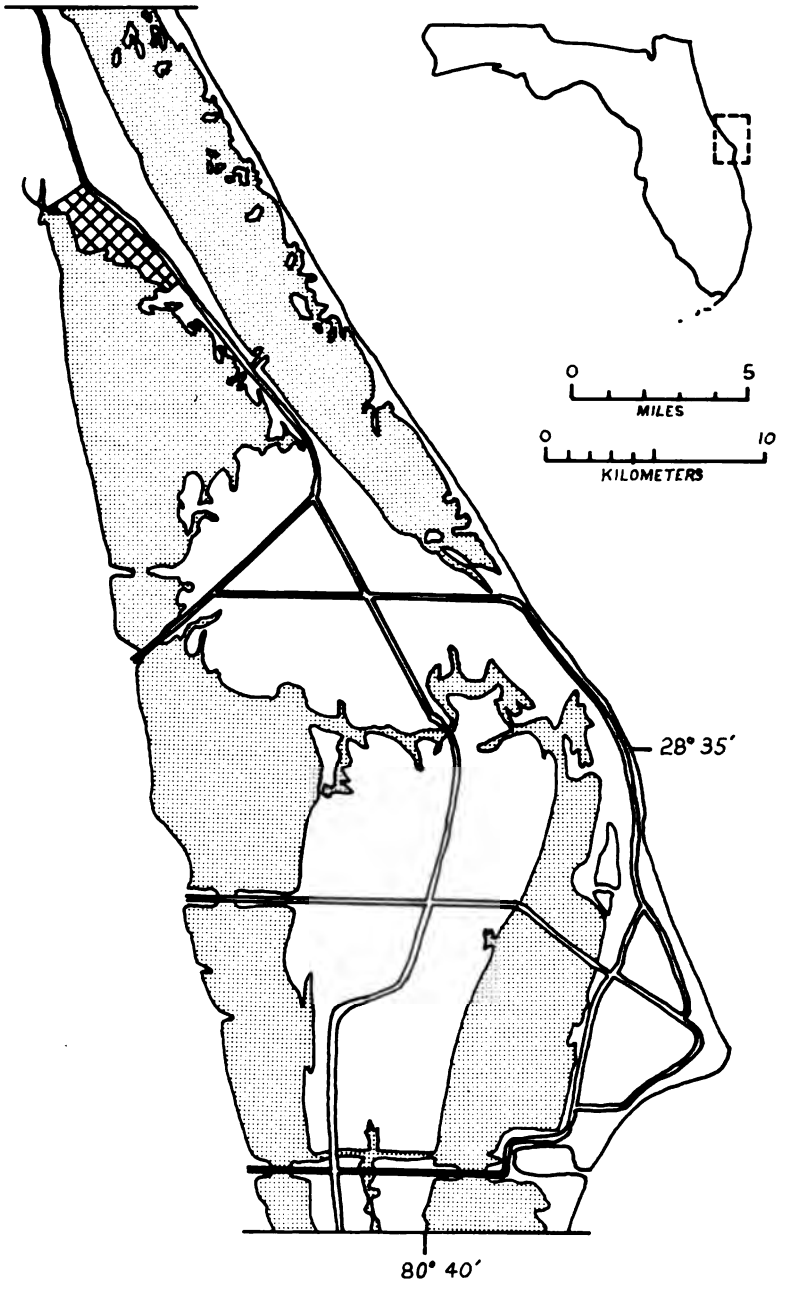


Fig. 1. Merritt Island National Wildlife Refuge. Shaded areas represent lagoonal waters. Study area for nesting habits is shown by cross-hatching.

1980a), and mating behavior (Seigel, 1980b), but nothing has been published concerning reproduction in this subspecies. The purpose of this paper is to compare the nesting habits, clutch size, and reproductive potential of *M. t. tequesta* to those of other subspecies.

## Materials and Methods

My investigations were conducted from January 1977 to April 1979 at the Merritt Island National Wildlife Refuge, Brevard County, Florida (Fig. 1). The refuge consists of three large brackish water lagoons, each surrounded by a series of dikes and brackish water impoundments, built in the late 1950's. The construction of these dikes resulted in the elimination of virtually all of the salt marsh on the refuge, so *Malaclemys* at Merritt Island are confined to the lagoons, or to the brackish water impoundments which surround them. A more detailed description of the study site is given elsewhere (Seigel, 1979).

Information concerning nesting habits was collected by walking two standardized 1.6 km census routes along a dike road on the northern boundary of the refuge (Fig. 1). Each route was checked 3–5 times daily during April–July, from 0700–0100. Turtles were collected by hand as they nested along the sides of the dike. Additional specimens were collected from a narrow canal bordering the study area. Straight-line carapace and plastron lengths (to the nearest 0.1 cm), and body weights (to the nearest 10 g) were recorded for each individual. Cloacal, substrate and shaded air temperatures were measured to the nearest 0.1 C with a Schultheis quick-reading thermometer. All turtles were marked and released at point of capture. Clutch size was determined by direct counts in natural nests, examination of corpora lutea, enlarged follicles and oviducal eggs, and by X-ray examination of gravid females (Gibbons and Greene, 1979). Eggs were incubated on moist soil in an open house trailer on the refuge. Eggs and hatchlings were measured to the nearest 0.1 cm with dial calipers, and weighed to the nearest 0.1 g on a Mettler balance.

All means are followed by ± one standard deviation. Student's t-tests were used to compare sample means.

## Results and Discussion

*Nesting habits.* Although numerous areas, including sand dunes, spoil islands, and the borders of the lagoons were surveyed for signs of nesting activity, nesting was observed only on dike roads. In contrast, other subspecies of *Malaclemys* nest almost exclusively on sand dunes, or in areas where sand dunes were historically present (Carr, 1952; Reid, 1955; Burger and Montevecchi, 1975; R. Wood, pers. comm.). Why Merritt Island terrapins do not nest on sand dunes is unknown. Distance from the water is

not an important barrier, since at least one lagoon (Fig. 1) is bordered quite closely by sand dunes. Conceivably, the soil of the dunes on the refuge is unsuitable for nesting. The only suitable nesting areas before the construction of the dikes in the late 1950's would have been the sandy borders of the lagoons. Although no nesting occurred in those areas during my study, it is likely that nesting was confined to those areas prior to 1960.

Gravid females were found from 6 May to 1 July in 1977 (57 days), and from 28 April to 18 June in 1978 (52 days). *Malaclemys t. terrapin* from New Jersey had a 44 day nesting season, extending from early June to late July (Burger and Montevecchi, 1975). All nesting in Florida occurred during daylight hours, from 1040 to 1610. Although air temperatures during surveys ranged from 24.4 to 36.2 C, nesting occurred only at temperatures of 28.0 to 36.0 C ($\bar{x}$ = 31.0 ± 1.9), and 83% of all nesting occurred between 29.0 and 33.0 C. Turtles also showed a significant preference for nesting during fair weather, rather than during periods of cloudy or overcast skies ($\chi^2$ = 5.11, d.f. = 1, $P < .05$). Other turtles, including *M. t. terrapin* (Burger and Montevecchi, 1975) and *Trionyx muticus* (Plummer, 1976) also have been found to nest primarily during fair weather.

*Clutch size and reproductive potential.* The mean size of 14 clutches, taken from natural nests, oviducal eggs, and X-ray examination, was 6.7 ± 1.4 (range 5–10). There was a significant positive correlation between female plastron length and clutch size (r = .53, $P < .05$). Montevecchi and Burger (1975) found a similar correlation for *M. t. terrapin*. Of eight Florida females examined for corpora lutea, two showed evidence of having laid two clutches, and one probably laid three. Multiple clutches have also been noted for *M. t. terrapin* (Hildebrand, 1932; R. Wood, pers. comm.) and *M. t. macrospilota* (D. Jackson, pers. comm.).

*Eggs and hatchlings.* Measurements of eggs and hatchlings are presented in Table 1. No significant correlations were found between clutch size and egg size, nor between female size and egg size. Montevecchi and Burger (1975) also found no correlation between these parameters.

Mean incubation time for five clutches incubated under temperatures of 20.0–34.0 C was 65.6 ± 5.3 days (range 60–73). Burger (1977) reported a mean incubation time of 76.2 days for *M. t. terrapin* eggs incubated under natural conditions. The lack of adequate temperature controls in this study make meaningful comparisons of these figures impossible. Of 31 eggs incubated, 29 (93.5%) hatched successfully.

*Geographic variation in reproduction.* Montevecchi and Burger (1975) suggested that *Malaclemys* showed considerable geographic variation in clutch size, and my data support that speculation. Available information concerning clutch size in *Malaclemys* is presented in Table 2. Clutch size varies from 9.7 eggs/clutch in New Jersey terrapins, to 6.7 eggs/clutch in *M. t. tequesta*. Similar reduction in clutch size in southern populations of

Table 1. Statistical data for 31 eggs and 29 hatchlings of *Malaclemys terrapin tequesta*. Length in cm, weight in g.

| Parameter | $\bar{x}$ ± SD | Range |
|---|---|---|
| Egg length | 3.90 ± .13 | 3.61–4.08 |
| Egg width | 2.23 ± .12 | 1.90–2.40 |
| Egg weight | 12.48 ± .73 | 11.20–13.20 |
| Carapace length | 3.19 ± .15 | 2.88–3.40 |
| Plastron length | 2.79 ± .14 | 2.42–3.02 |
| Hatchling weight | 8.83 ± .15 | 6.00–10.80 |

turtles has been reported for *Sternotherus odoratus* (Tinkle, 1961), and *Chrysemys picta* (Powell, 1967; Christiansen and Moll, 1973; Moll, 1973). The significance of this trend in *Malaclemys* is in part reduced by the small number of populations examined, and by the fact that considerable variation in clutch size can occur between local populations of some species (Gibbons and Tinkle, 1969). More populations of *Malaclemys* need to be studied to confirm this trend.

Perhaps a more significant geographic trend is that for egg size (Table 3). Eggs of Florida terrapins are significantly larger in both length and weight than eggs of *M. t. terrapin* or *M. t. pileata* (t-test, $P < .01$). Florida hatchlings were also significantly larger than their northern counterparts, but since these measurements may be affected by soil moisture during incubation (Marion et al., 1979; Packard and Packard, 1980), they are not compared here. Although it is conceivable that egg size could vary as greatly between populations as does clutch size, no such variation has been reported, and in general, mean egg size appears to be fairly uniform within a subspecies (Christiansen and Moll, 1973; Iverson, 1979), although individual egg size may vary widely (Ewert, 1979).

Table 2. Comparison of clutch size and reproductive potential in various subspecies of *Malaclemys*.

| Subspecies | Locality | Authority | $\bar{x}$ clutch size (range) | # of clutches | N |
|---|---|---|---|---|---|
| *terrapin* | New Jersey | Montevecchi and Burger (1975) | 9.7 (4–18) | 1 | 40 |
| *terrapin* | Virginia | Reid (1955) | 7.0 (—) | 1 | 1 |
| *terrapin* × *centrata** | N. Carolina | Hildebrand (1932) | 8.0 (—) | 1–5 | — |
| *pileata** | Louisiana | Burns and Williams (1972) | 8.5 (5–12) | 1 | 11 |
| *tequesta* | Florida | This study | 6.7 (5–10) | 1–3 | 14 |

* Captive specimens.

Table 3. Mean sizes of *Malaclemys terrapin* eggs from various parts of the range. Measurement ranges are given in parentheses.

| | *terrapin* (I) | *terrapin* (II) | *pileata* | *tequesta* |
|---|---|---|---|---|
| Locality | New Jersey | Maryland | Louisiana | Florida |
| Authority | Montevecchi and Burger (1975) | McCauley (1945) | Burns and Williams (1972) | This study |
| Egg length | 3.16 (2.60–3.65) | 3.11 (2.85–3.50) | 3.73 (3.40–4.01) | 3.90 (3.61–4.08) |
| Egg width | 1.97 (1.59–2.19) | 2.12 (2.00–2.25) | 2.39 (2.19–2.70) | 2.23 (1.90–2.40) |
| Egg weight | 7.7 (5.0–11.0) | — | — | 12.48 (11.20–13.20) |
| N | 336 | 12 | 95 | 31 |

It has been suggested (Tinkle, 1961; Tinkle et al., 1970; Pianka, 1970) that because of high abiotic mortality in northern climates, selection there might favor increased fecundity. In southern or tropical areas, where abiotic mortality may be less important and populations may approach the carrying capacity, selection might favor increased survivorship and competitive ability among offspring, while reducing fecundity. The apparent shift in *Malaclemys* from large clutch size/small egg size in the north, to small clutch size/large egg size in the south, appears to conform to these ideas. Moll and Legler (1971) reported similar trends in egg size in *Kinosternon*. Large egg size may result in higher offspring survivorship by providing greater food reserves during development (Moll and Legler, 1971), by decreasing incubation time and thus increasing the amount of time available for hatchling growth (Burger, 1977), and by producing a larger hatchling which may be less vulnerable to some predators (Moll and Legler, 1971). Higher survivorship among larger offspring has been reported for some lizards (Derickson, 1976; Ferguson and Bohler, 1978) and for one turtle (Swingland and Coe, 1979).

Moll (1979) suggested that reproductive strategies in turtles may be divided into two types: Type I—large clutches of small eggs laid in a well-defined area and nesting season; Type II—small clutches of large eggs laid continuously and apparently at random. Type I is characteristic of temperate species, while Type II is more characteristic of tropical areas. Considerable overlap may occur however, so the above dichotomy is not complete. Moll also suggested that the Type II pattern may result in increased survivorship of offspring while sacrificing fecundity, the opposite of the Type I pattern. Florida *Malaclemys* may be intermediate between the two types, laying small clutches of relatively large eggs in a well-defined area, and in a definite, if elongated nesting season. It is possible that this strategy represents an adaptation to the subtropical environment of *M. t. tequesta*.

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For help with the fieldwork, I thank E. Scott Clark, Timothy R. Claybaugh, John D. Galluzzo, Mary T. Mendonca, and Sherry E. Wiliams. Dale Jackson discussed the use of oxytocin, and helped examine specimens for corpora lutea. I thank J. Whitfield Gibbons for advice on the use of X-rays, and Jo Guren and Alan Bosemany for use of hospital equipment. Jeffrey D. Wetherington helped with the statistical analysis. The U.S. Fish and Wildlife Service made field sites available, and provided logistical support. Various drafts of this manuscript were improved by the critical reviews of William E. Duellman, Henry S. Fitch, Mary T. Mendonca, Peter C. H. Pritchard, Michael Ryan, I. Jack Stout, and Roger C. Wood. My wife, Nadia, was a constant help, both in the field and during preparation of the manuscript. I particularly thank the late James D. Anderson for advice and encouragement. This research was supported by NASA Contract NAS10-8986, to L. M. Ehrhart, who made financial support available.

## Literature Cited

Burger, J. 1976a. Behavior of hatchling diamondback terrapins (*Malaclemys terrapin*) in the field. Copeia 1976:742–748.

Burger, J. 1976b. Temperature relationships in nests of the diamondback terrapin, *Malaclemys terrapin terrapin*. Herpetologica 32:412–418.

Burger, J. 1977. Determinants of hatching success in diamondback terrapin, *Malaclemys terrapin*. Amer. Midl. Natur. 97:444–464.

Burger, J., and W. A. Montevecchi. 1975. Nest site selection in the terrapin *Malaclemys terrapin*. Copeia 1975:113–119.

Burnley, J. M. 1969. Diamondback terrapin. Int. Turtle and Tortoise Soc. J. 3:32–34.

Burns, T., and K. Williams. 1972. Notes on the reproductive habits of *Malaclemys terrapin pileata*. J. Herpetol. 6:238–239.

Carr, A. F. 1952. Handbook of turtles. Comstock Publ. Assoc. Ithaca, New York.

Christiansen, J. L., and E. O. Moll. 1973. Latitudinal reproductive variation within a single subspecies of painted turtle, *Chrysemys picta bellii*. Herpetologica 29:152–163.

Derickson, W. K. 1976. Ecological and physiological aspects of reproductive strategies in two lizards. Ecology 57:445–458.

Ewert, M. A. 1979. The embryo and its egg: development and natural history. *in* Turtles, Perspectives and Research, M. Harless and H. Morlock, eds. p. 333–413.

Ferguson, G. W., and C. H. Bohlen. 1978. Demographic analysis: a tool for the study of natural selection of behavioral traits. *in* Behavior and Neurobiology of Lizards, N. Greenburg and P. D. MacLean, eds. p. 227–243.

Finneran, L. C. 1948. Diamondback terrapin in Connecticut. Copeia 1948:138.

Gibbons, J. W., and D. W. Tinkle. 1969. Reproductive variation between turtle populations in a single geographic area. Ecology 50:340–341.

Gibbons, J. W., and J. L. Greene. 1979. X-ray photography: a mechanism to determine reproductive patterns in freshwater turtles. Herpetologica 35:86–89.

Hildebrand, S. F. 1929. Review of experiments on artificial culture of diamondback terrapin. Bull. U.S. Bur. Fish. 45:25–70.

Hildebrand, S. F. 1932. Growth of diamondback terrapins: size attained, sex ratio and longevity. Zoologica 9:551–563.

Iverson, J. B. 1979. Reproduction and growth of the mud turtle, *Kinosternon subrubrum* (Reptilia: Testudines: Kinosternidae), in Arkansas. J. Herpetol. 13:105–111.

Marion, K. R., J. B. Bizer, and O. J. Sexton. 1979. A between-clutch comparison of hatchling weights of the lizard *Sceloporus undulatus* (Reptilia: Squamata: Lacertilia). Herpetologica 35:111–114.

McCauley, R. H. 1945. The reptiles of Maryland and the District of Columbia. Privately printed, Hagerstown, Maryland.

Moll, E. O. 1973. Latitudinal and interspecific variation in reproduction of the painted turtle, *Chrysemys picta*. Herpetologica 29:307–318.

Moll, E. O. 1979. Reproductive cycles and adaptations. *in* Turtles, Perspectives and Research, M. Harless and H. Morlock, eds., p. 305–331.

Moll, E. O., and J. M. Legler. 1971. The life history of a neotropical slider, *Pseudemys scripta* (Schoepff), in Panama. Bull. Los Angeles Co. Mus. Nat. Hist. Sci. 11:1–102.

Montevecchi, W. A., and J. Burger. 1975. Aspects of the reproductive biology of the northern diamondback terrapin *Malaclemys terrapin terrapin*. Amer. Midl. Natur. 104:592–597.

Packard, G. C., and M. J. Packard. 1980. Evolution of the cleidoic egg among reptilian antecedents of birds. Amer. Zool. 20:351–362.

Pianka, E. R. 1970. On r and K selection. Amer. Natur. 104:592–597.

Plummer, M. V. 1976. Some aspects of the nesting success in the turtle, *Trionyx muticus*. Herpetologica 32:353–359.

Powell, C. B. 1967. Female sexual cycles of *Chrysemys picta* and *Clemmys insculpta* in Nova Scotia. Can. Field. Natur. 81:134–140.

Reid, G. K. 1955. Reproduction and development in the diamondback terrapin, *Malaclemys terrapin terrapin*. Copeia 1955:310–311.

Seigel, R. A. 1978. Simultaneous mortality in the diamondback terrapin, *Malaclemys terrapin tequesta* (Schwartz). Bull. N.Y. Herpetol. Soc. 14:31–32.

Seigel, R. A. 1979. The reproductive biology of the diamondback terrapin, *Malaclemys terrapin tequesta*. Master's thesis, University of Central Florida, Orlando. 40 pp.

Seigel, R. A. 1980a. Predation by raccoons on diamondback terrapins, *Malaclemys terrapin tequesta*. J. Herpetol. 14:87–89.

Seigel, R. A. 1980b. Courtship and mating behavior of the diamondback terrapin, *Malaclemys terrapin tequesta*. J. Herpetol. in press.

Swingland, I. R., and M. J. Coe. 1979. The natural regulation of giant tortoise populations on Aldabra Atoll: Recruitment. Philos. Trans. R. Soc. London Ser. B 286:177–188.

Tinkle, D. W. 1961. Geographic variation in reproduction, size, sex ratio, and maturity of *Sternothaerus odoratus* (Testudinata, Chelydridae). Ecology 42:68–76.

Tinkle, D. W., H. M. Wilbur, and S. G. Tilley. 1970. Evolutionary strategies in lizard reproduction. Evolution 24:55–74.

# Errata

The abstract entitled "The origins of homoiothermy" by Eleanor Daly, which appeared on page 127 of the August, 1980 number of *Transactions* (vol. 83:3), should read:

THE ORIGINS OF HOMOIOTHERMY. Daly, Eleanor, Department of Systematics and Ecology, University of Kansas, Lawrence, Kansas 66045.

Many, if not most, ectotherms have a body temperature range to which they are adapted, in which they enjoy maximum physiological efficiency. They seek this activity temperature range by behavioral means before beginning to forage. If an animal's body temperature were constantly at its optimum, it would be constantly at its maximum speed and strength. However, the energetic cost of a high constant BMR is very great. According to the hypothesis of Bennett and Ruben (1979), thermoregulation was not the original selective advantage of endothermic homoiothermy. A high constant body temperature confers a capacity for sustained vigorous activity, because the resting rate of oxygen consumption is related to the maximum rate. Early mammals were small nocturnal animals. We know this because of the peculiarities of their vision, and the high development of their senses of hearing and smell. It is difficult to control body temperature by ectothermic means after dark. By adopting homoiothermy, the ancestors of mammals took over the later part of the night, free of reptilian competition and predation. The treadmill experiments reported by Crompton, Taylor and Jagger (1978) show that living primitive placentals have low metabolic rates. Therefore, the original selective pressure for mammalian homoiothermy was thermoregulatory and the hypothesis of Bennett and Ruben does not apply. Avian homoiothermy is reasonably thought to be connected with flight, which certainly requires a capacity for sustained vigorous activity. Birds fly with their feathers, and their feather cover must have appeared together with homoiothermy. We need not suppose that homoiothermy developed before flight, if we can believe that the proavis glided on skin membranes, as do all other vertebrate fliers and gliders. With powered flight, homoiothermy and insulation were selected for. Eventually, lengthening wing feathers replaced the patagium. The hypothesis of Bennett and Ruben can be applied to birds, and also to pterosaurs in the same way.

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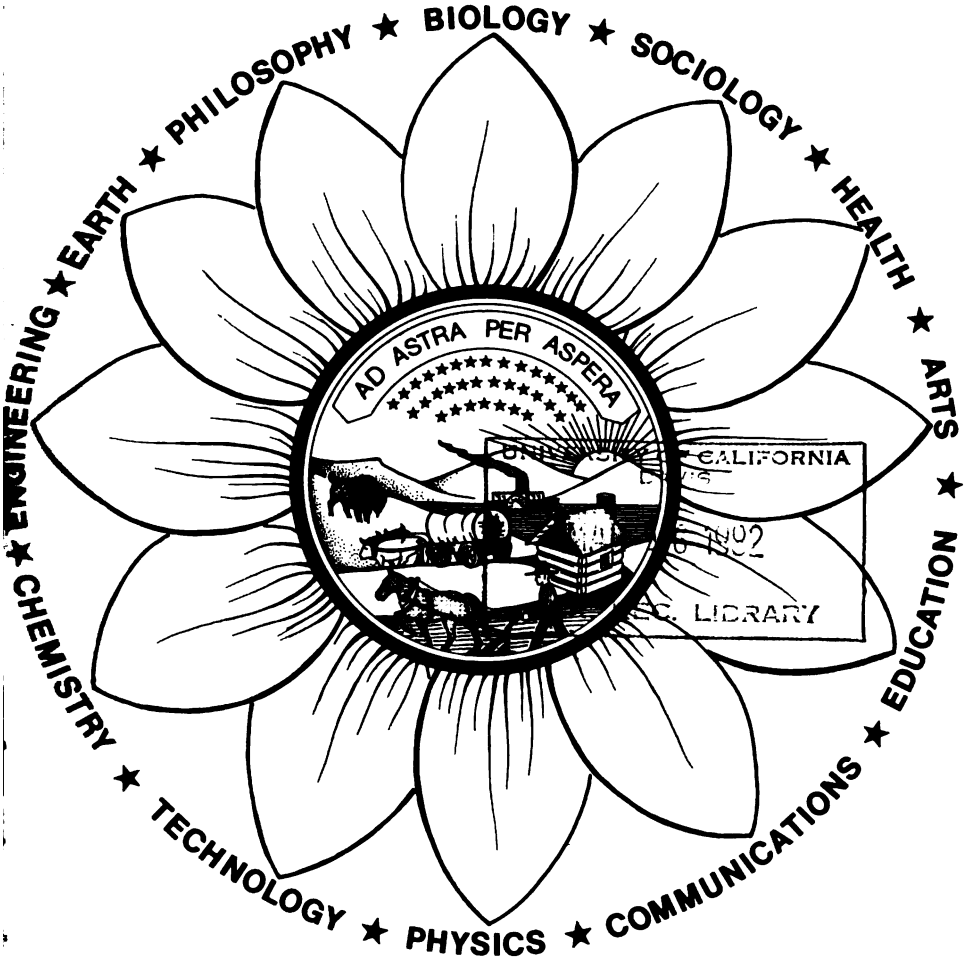


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# Heritability and Interrelationships of Chemical and Agronomic Traits of Soybeans (*Glycine max* [L.] Merr.) in Diverse Environments[1]

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ABSTRACT

Heritabilities and interrelationships of chemical and agronomic traits of soybeans were determined in high-seed yield, irrigated environments and low-seed yield nonirrigated stress environments.

Seed yield was correlated with economic growth rate (EGR), biological yield, growth rate, EGR-fruiting period, harvest index, seed weight, oil content, seed quality, unmottled seed, height, low protein, and resistance to lodging, shattering, and drought. Associations measured indicated that greater progress toward increased seed yield can be made by selecting for growth rate or biological yield than for harvest index. Seed yield was positively correlated with maturity in the nonirrigated environment and negatively correlated with maturity under irrigation. Protein and oil content (chemical traits) were negatively correlated.

Interannual correlations suggested that seed quality was as subject to environmental differences as was seed yield, and that phenotypic stability was greater in the irrigated than in the nonirrigated environment. Estimates of heritability were larger in the irrigated than in the nonirrigated environment or for soybean populations selected from the irrigated than from the nonirrigated environment. Greater genetic progress can be expected when selection is performed in an irrigated environment.

Heritabilities and interrelationships of chemical and agronomic traits of soybeans have been presented by several authors (Anand and Torrie, 1963; Byth et al., 1969; Hanson and Weber, 1962; Johnson et al., 1955a; Kwon

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Table 1. Pedigree and cross number of soybean populations used in study.

| Cross no. | Parentage |
|---|---|
| K71-109 | Williams × Bonus |
| K71-122 | (Amsoy × FC 31.122) × Calland |
| K71-136 | [(Lincoln × Ogden) × Clark] × [Clark 63 × (Sioux × Clark)] |
| K71-153 | [Wayne × (Clark × Adams)] × Bonus |

and Torrie, 1964; Mahmud and Kramer, 1951; Schutz and Bernard, 1967; Weber and Moorthy, 1952; Weiss and Weber, 1952). Most estimates of heritability for seed yield and components of yield, except seed weight, have been low, and heritabilities for seed weight, protein content, oil content, and other agronomic traits have been high (Anand and Torrie, 1963; Hanson and Weber, 1962; Johnson et al., 1955; Kwon and Torrie, 1964; Mahmud and Kramer, 1951; Schutz and Bernard, 1967; Weber and Moorthy, 1952). According to Johnson et al. (1955b) environmental effects account for the failure of the yields of soybean lines to indicate the yields of their progeny.

Harvest index, the ratio of seed yield to biological yield, has interested plant scientists (Fischer and Kertesz, 1976; Rosielle and Frey, 1975; Singh and Stoskopf, 1971; Wallace and Munger, 1966). For soybeans, Weber et al. (1970) found that whole-plant dry weight was larger and harvest index smaller for the $F_1$ hybrids than for the high parent, indicating that increased seed yield of the $F_1$ was related to increased biological yield and not to harvest index.

Green et al. (1971) studied the heritability of six soybean seed quality characters and suggested that to improve seed quality an overall visual rating of the seed would be more efficient than rating individual seed characters. Schutz and Bernard (1967) found the magnitude of the genotype environment interaction to be as large for seed quality as for seed yield indicating low heritability for seed quality.

Because previous experiments (Anand and Torrie, 1963; Byth et al., 1969; Johnson, 1955a, 1955b) were conducted in moderate-yield environments resulting in mean yields of 2200 to 2900 kg/ha, the objective in this experiment was to determine heritability and interrelationships of chemical and agronomic traits of soybeans in high-yield, irrigated environments and in nonirrigated, stress environments.

## Materials and Methods

Four bulk $F_3$ soybean populations were planted at two locations in 1974 at the Kansas State University Agronomy Farm, Manhattan, Kansas (Table 1). At one location with a Muir silt loam soil (fine-silty, mixed mesic Pachic Haplustolls), moisture was provided throughout the growing season through

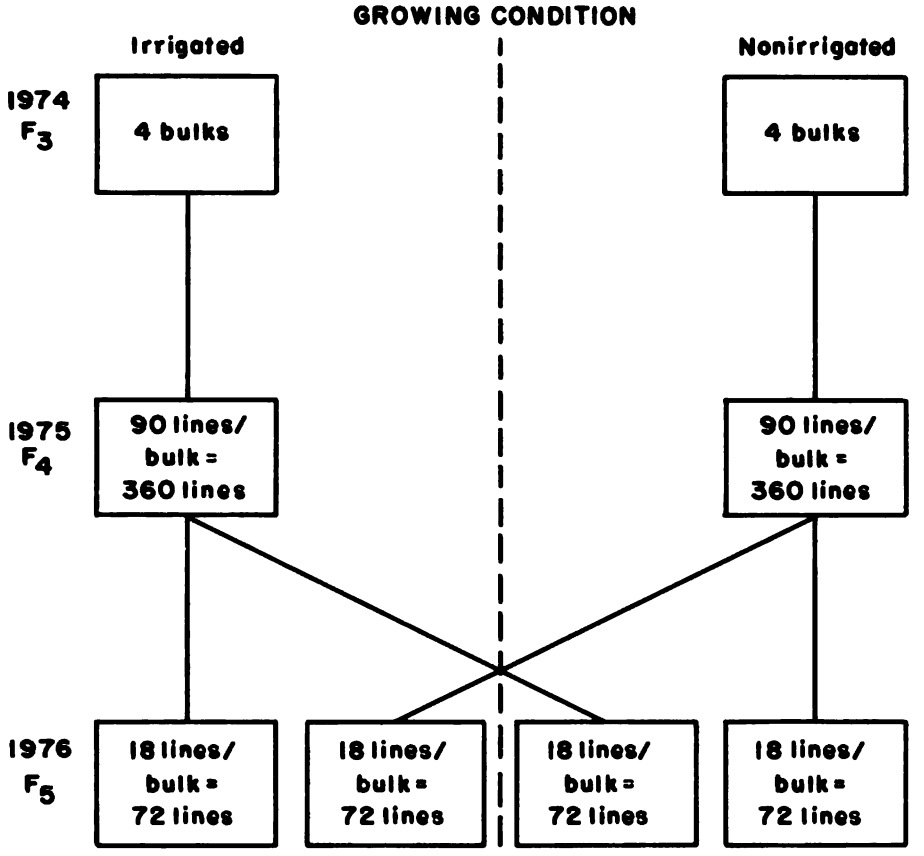


Fig. 1. Scheme for selecting materials grown in two environments, irrigated and nonirrigated.

furrow irrigation; the other location which had Haynie very fine sandy loam soil (coarse-silty, mixed calcareous, mesic Typic Udifluvents), was not irrigated. At maturity, 90 plants were randomly selected from each population at both locations (Fig. 1). In 1975, progeny rows were grown from the seed of the selected plants in their respective environments of selection. Rows were 3 m long with 76 cm spacings between rows. Seed of standard cultivars and $F_4$ bulks were planted among the $F_3$-derived lines alternating every tenth row to measure environmental uniformity. Rows were trimmed to 2.4 m for harvest. The highest and lowest yielding 10% of the lines in each population from each environment were selected. In 1976, selected lines and checks were arranged in a randomized block design with two replications at both locations. Plots were two 3 m long rows with 76-cm spacings between the rows; both rows were trimmed to 2 m for harvest.

Table 2. Definition of characters and years in which data were taken.

| Year | | | |
|---|---|---|---|
| 1975 | 1976 | Character | Definition |
| X | X | Seed yield | Seed yield in kg/ha at 13% moisture. |
| X | X | Economic growth rate (EGR) | Yield divided by growth duration. |
| X | X | Biological yield | Total aerial biological yield, dry weight in kg/ha. |
| X | X | Growth rate | Biological yield divided by growth duration. |
| X | X | Harvest index | Percentage of biological yield that represents seed yield. |
| X | X | Seed weight | Seed weight in grams per 100 seeds. |
| X | X | Maturity | Number of days from January 1 to the date when 95% of the pods are ripe. |
| X | X | Height | Height at maturity in cm. |
| X | X | Seed quality | Scored from 1 to 5, with 1 indicating excellent seed quality and 5 very poor. |
| X | X | Seed mottling | Scored from 1 to 5, with 1 indicating no mottling and 5 all seed completely mottled. |
| X | X | Oil percentage | Oil percentage on dry weight basis. |
| X | X | Protein percentage | Protein percentage on dry weight basis. |
| X | X | Chemical constituents | Oil plus protein percentages on dry weight basis. |
| X | X† | Shattering | Scored from 1 to 5 at maturity, with 1 indicating no shattering and 5 complete shattering. |
| X† | X† | Lodging | Scored from 1 to 5 at maturity, with 1 indicating plants erect and 5 all plants prostrate. |
| X† | | Early lodging | Lodging scored August 18. |
| | X | First flower | Number of days from planting till 5% of the plants were flowering. |
| | X | Last flower | Number of days from planting till few remaining flowers. |
| | X | Length of flowering | Number of days from first flower to last flower. |
| | X | Bacterial blight *Pseudomonas glycinea* | Scored from 1 to 5, with 1 indicating no lesions on leaves and 5 with lesions covering all leaves. |
| | X | Canopy shape | Scored from 1 to 5, with 1 indicating a closed canopy and 5 an open canopy. |

Table 2. Continued.

| Year 1975 | Year 1976 | Character | Definition |
|---|---|---|---|
| | X | EGR-fruiting period | Yield divided by fruiting duration, number of days from last flower to maturity. |
| | X† | Physiological maturity | Number of days from January 1 to the date when 90% of the leaves were yellow. |
| | X‡ | Drought | Scored from 1 to 5, with 1 indicating no visual drought effects and 5 being premature death due to drought. |

† Measured in the irrigated environment only.
‡ Measured in the nonirrigated environment only.

The data collected in 1976 for each population within both selection sources at both locations were analyzed for each character (Table 2) by analysis of variance, random model. Mean squares were pooled for populations over sources or locations. Variance components ($\hat{\sigma}_e^2$, $\hat{\sigma}_g^2$) were substituted for the parameters in the following formula to obtain pooled estimates of heritability:

$$\text{Heritability (H)} = \frac{\hat{\sigma}_g^2}{\hat{\sigma}_{ph}^2} \frac{\text{(genotypic variance)}}{\text{(phenotypic variance)}}$$

where $\hat{\sigma}_{ph}^2 = \hat{\sigma}_g^2 + \frac{\hat{\sigma}_e^2}{r}$ is the phenotypic variance among the means of the lines compared in r replications (Table 3).

Heritabilities were biased upward because the interaction variances of families × locations and families × years are included in the genotypic variance, $\hat{\sigma}_g^2$.

Pooled-within-cell correlation coefficients were computed for soybean characters across populations within environments for 1975 (Table 4) and across populations and sources within environments for 1976 (Table 5), and also between years, and/or environments (Table 6). Means of the two replications of lines grown in 1976 were used in the correlation computations. Genotypic correlations were calculated across locations according to Grafius (1966).

## Results and Discussion

Average seed yield and economic growth rate (EGR) of soybean lines were similar for the irrigated location in 1975 and 1976, even though bio-

Table 3. Heritabilities of soybean characters for locations and sources (1976).

| Trait | Environment selected from in 1975† | | Environment grown in 1976‡ | |
|---|---|---|---|---|
| | Irrigated | Nonirrigated | Irrigated | Nonirrigated |
| Seed yield | 37.2 | 28.4 | 33.0 | 33.4 |
| EGR | 41.6 | 28.2 | 33.6 | 39.6 |
| Biological yield | 25.8 | 35.2 | 35.0 | 21.6 |
| Growth rate | 26.8 | 30.0 | 28.4 | 29.0 |
| Harvest index | 48.2 | 29.4 | 50.0 | 35.8 |
| Seed weight | 61.4 | 60.8 | 81.2 | 42.6 |
| Maturity | 75.4 | 53.4 | 76.8 | 63.6 |
| Height | 69.6 | 52.6 | 59.8 | 61.0 |
| Seed quality | 63.0 | 53.8 | 69.0 | 46.6 |
| Seed mottling | 78.4 | 64.6 | 78.0 | 47.4 |
| Oil % | 74.6 | 76.4 | 82.4 | 69.2 |
| Protein % | 80.0 | 79.8 | 81.2 | 78.6 |
| Chemical constituents | 66.6 | 65.4 | 71.6 | 62.6 |
| First flower | 74.8 | 69.2 | 79.2 | 60.2 |
| Last flower | 51.4 | 47.2 | 57.0 | 24.0 |
| Length of flowering | 46.6 | 28.2 | 46.2 | 22.4 |
| Bacterial blight | 21.0 | 13.0 | 24.4 | −0.9 |
| Canopy shape | 60.8 | 39.2 | 44.0 | 62.0 |
| EGR-fruiting period | 51.1 | 17.8 | 28.8 | 53.6 |

† Mean squares were pooled over 1976 locations for populations selected from the 1975 irrigated or 1975 nonirrigated environments to estimate heritabilities for source of selections.

‡ Mean squares were pooled for all populations within the irrigated or nonirrigated environments to obtain estimates of heritability.

logical yield was lower in 1976 (Table 7). For the nonirrigated environment, mid- and late-summer drought in 1976 reduced seed yields, seed quality, seed weight, and caused plants to mature earlier. However, plants were taller in 1976 due to favorable early summer growing conditions. Thus biological yield was about equal for the two years, but harvest index was lower in 1976. When compared to the non-irrigated environment, seed yield, EGR, biological yield, growth rate, and EGR-fruiting period averages were larger under irrigation for both years. Oil, protein, and chemical constituents were similar in both environments in 1975 but significantly different in 1976.

Yield was positively correlated with EGR, biological yield, growth rate, EGR-fruiting period, and harvest index (Tables 4 and 5). Harvest index was not so strongly associated with seed yield as with the other previously mentioned characters in three of the four environments. As Rosielle and Frey (1975) and Takeda and Frey (1976) observed in oats, selection for growth rate or biological yield should result in greater seed yield increase than would selection for harvest index. Seed weight oil content, and height tended to be positively associated with seed yield, as has been reported previ-

Table 4. Correlation matrix of soybean characters observed in the irrigated environment, right side of diagonal, and nonirrigated environment, left side of diagonal (1975).*

| | 1 Seed yield | 2 EGR | 3 Bio. yield | 4 Growth rate | 5 Harvest index | 6 Seed weight | 7 Matu-rity | 8 Height | 9 Seed quality | 10 Mottl-ing | 11 Oil % | 12 Protein % | 13 Chem. const. | 14 Shat-tering | 15 Lodg. | 16 Early lodg. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | .98 | .66 | .76 | .58 | .30 | −.16 | −.03 | −.15 | −.18 | .39 | −.42 | −.10 | −.36 | −.12 | −.14 |
| 2 | .98 | | .55 | .69 | .68 | .34 | −.38 | −.12 | −.15 | −.17 | .42 | −.42 | −.06 | −.41 | −.06 | −.04 |
| 3 | .79 | .75 | | .96 | −.21 | −.05 | .34 | .28 | −.10 | −.14 | .07 | −.18 | −.17 | −.04 | −.10 | −.23 |
| 4 | .74 | .77 | .96 | | −.04 | .02 | .06 | .18 | −.12 | −.14 | .14 | −.22 | −.13 | −.14 | −.05 | −.14 |
| 5 | .64 | .65 | .04 | .02 | | .46 | −.59 | −.36 | −.08 | −.07 | .45 | −.37 | .05 | −.44 | −.02 | .09 |
| 6 | .04 | .09 | .01 | .07 | .05 | | −.25 | −.16 | .12 | −.18 | .45 | −.32 | .13 | −.02 | .08 | .10 |
| 7 | .29 | .07 | .31 | .03 | .08 | −.22 | | .41 | .03 | −.01 | −.24 | .10 | −.16 | .34 | −.20 | −.37 |
| 8 | .37 | .36 | .35 | .34 | .16 | .07 | .10 | | −.24 | −.11 | .13 | −.19 | −.10 | .16 | −.04 | −.19 |
| 9 | −.28 | −.21 | −.30 | −.23 | −.08 | .44 | −.31 | −.16 | | .09 | −.19 | .24 | .09 | .03 | .12 | .09 |
| 10 | −.01 | −.02 | −.01 | −.01 | −.02 | −.22 | .02 | .02 | −.28 | | −.25 | .20 | −.03 | −.02 | .07 | .10 |
| 11 | .07 | .08 | .10 | .13 | −.03 | .18 | −.08 | .17 | .11 | −.19 | | −.72 | .25 | −.13 | .02 | .01 |
| 12 | −.23 | −.20 | −.27 | −.25 | −.02 | −.02 | −.14 | −.26 | .12 | .03 | −.61 | | .49 | .18 | .06 | .09 |
| 13 | −.21 | −.16 | −.23 | −.17 | −.06 | .15 | −.24 | −.15 | .26 | −.15 | .23 | .63 | | .10 | .10 | .14 |
| 14 | −.37 | −.33 | −.15 | −.06 | −.45 | .01 | −.30 | −.11 | .11 | −.04 | .24 | −.09 | .13 | | −.04 | −.05 |
| 15 | | | | | | | | | | | | | | | | .78 |
| 16 | | | | | | | | | | | | | | | | |

* For $P = 0.05$, $r = 0.11$; for $P = 0.01$, $r = 0.13$.

Table 5. Correlation matrix of characters of selected soybean lines in the irrigated environment, right side of diagonal, and nonirrigated environment, left side of diagonal (1976).*

| | 1 Seed yield | 2 EGR | 3 Bio. yield | 4 Growth rate | 5 Harvest index | 6 Seed weight | 7 Maturity | 8 Height | 9 Seed quality | 10 Mottling | 11 Oil % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | .95 | .70 | .73 | .48 | .09 | −.04 | −.11 | −.11 | −.15 | .30 |
| 2 | .98 | | .59 | .72 | .55 | .09 | −.34 | −.17 | −.05 | −.17 | .26 |
| 3 | .77 | .73 | | .94 | −.28 | −.06 | .22 | .23 | −.16 | −.12 | .20 |
| 4 | .64 | .69 | .90 | | −.17 | −.06 | −.12 | .16 | −.10 | −.16 | .19 |
| 5 | .90 | .90 | .47 | .38 | | .24 | −.30 | −.46 | .07 | −.03 | .15 |
| 6 | .51 | .41 | .34 | .08 | .49 | | −.03 | −.19 | .34 | −.01 | .01 |
| 7 | .28 | .09 | .25 | −.20 | .24 | .57 | | .23 | −.20 | .07 | .05 |
| 8 | .40 | .34 | .25 | .08 | .42 | .35 | .38 | | −.23 | .05 | −.01 |
| 9 | .07 | .08 | .02 | .03 | .06 | −.03 | −.05 | .12 | | .08 | −.11 |
| 10 | .28 | .28 | .25 | .24 | .22 | .11 | .02 | .08 | .12 | | −.11 |
| 11 | .29 | .28 | .26 | .24 | .25 | .25 | .09 | .20 | −.02 | −.03 | |
| 12 | .09 | .04 | .08 | −.04 | .07 | .17 | .22 | .11 | −.02 | .14 | −.78 |
| 13 | .41 | .34 | .37 | .17 | .36 | .49 | .41 | .36 | −.05 | .19 | −.26 |
| 14 | −.18 | −.24 | .02 | −.10 | −.23 | .06 | .26 | −.05 | −.02 | .01 | −.13 |
| 15 | .22 | .14 | .28 | .08 | .15 | .29 | .45 | .36 | −.07 | .05 | −.03 |
| 16 | .33 | .31 | .23 | .15 | .31 | .20 | .18 | .35 | −.06 | .05 | .08 |
| 17 | −.09 | −.11 | −.01 | −.06 | −.13 | .01 | .10 | −.14 | −.08 | .03 | −.15 |
| 18 | .20 | .23 | .03 | .07 | .27 | −.08 | −.12 | .35 | .28 | .10 | .11 |
| 19 | .80 | .90 | .57 | .70 | .77 | .16 | −.26 | .21 | .06 | .25 | .21 |
| 20 | −.42 | −.33 | −.33 | −.04 | −.42 | −.48 | −.66 | −.29 | .16 | −.11 | −.05 |
| 21 | | | | | | | | | | | |
| 22 | | | | | | | | | | | |

ously (Anand and Torrie, 1963; Byth et al., 1969; Weber and Moorthy, 1952). Seed yield tended to be negatively correlated with protein, lodging susceptibility, poor seed quality, mottled seed, shattering, and drought susceptibility, also as has been reported previously (Anand and Torrie, 1963; Byth et al., 1969; Johnson et al., 1955a). In the 1975 irrigated environment seed yield was negatively correlated with maturity date. However, in the nonirrigated environment, the opposite was true with seed yield correlated with lateness for first and last flower and maturity. Previously, researchers (Anand and Torrie, 1963; Byth et al., 1969; Johnson et al., 1955a; Weiss et al., 1952) have found seed yield to be associated with late maturity. Late maturing soybean cultivars in nonirrigated environments can make use of fall rains which come too late for earlier cultivars. These data suggest that for this environment when soybeans are grown under irrigation, late maturity is not an asset and late genotypes can be lower in yield than earlier-maturing lines. Soybean lines evaluated in the irrigated environment should be compared with adapted cultivars of like maturity to determine whether they should be saved. Correlations between seed yield and other soybean

Table 5. Continued.

| | 12 Protein % | 13 Chem. const. | 14 First flower | 15 Last flower | 16 Length flower | 17 Bact. blight | 18 Canopy shape | 19 EGR-fruit. | 20† P. mat./ drought | 21 Lodg. | 22 Shat-tering |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | −.21 | −.03 | −.02 | −.15 | −.13 | −.10 | .03 | .60 | .06 | −.02 | −.38 |
| 2 | −.14 | .06 | −.15 | −.22 | −.11 | −.12 | .07 | .74 | −.20 | −.01 | −.43 |
| 3 | −.22 | −.18 | .21 | .16 | .03 | −.20 | .11 | .40 | .38 | .08 | −.14 |
| 4 | −.17 | −.09 | .06 | .07 | .04 | −.23 | .16 | .61 | .10 | .10 | −.21 |
| 5 | .01 | .19 | −.29 | −.42 | −.22 | .10 | −.08 | .29 | −.39 | −.13 | −.33 |
| 6 | .20 | .39 | −.16 | −.25 | −.13 | −.19 | −.04 | −.06 | −.10 | .05 | .05 |
| 7 | −.18 | −.28 | .44 | .30 | −.02 | .09 | −.13 | −.56 | .85 | −.07 | .20 |
| 8 | −.04 | −.11 | .30 | .38 | .18 | −.13 | .11 | .01 | .36 | .30 | .08 |
| 9 | .18 | .20 | −.22 | −.28 | −.13 | −.04 | .20 | −.10 | −.27 | .06 | .04 |
| 10 | .14 | .12 | .16 | −.02 | −.13 | −.01 | −.04 | −.19 | .06 | .05 | .01 |
| 11 | −.87 | −.43 | .10 | .06 | −.01 | −.05 | .01 | .20 | .17 | .21 | −.15 |
| 12 | | .82 | −.16 | −.23 | −.12 | −.01 | .03 | −.15 | −.32 | −.23 | .05 |
| 13 | .80 | | −.21 | −.37 | −.23 | −.06 | .07 | −.04 | −.40 | −.18 | −.08 |
| 14 | .16 | .12 | | .36 | −.35 | .12 | −.23 | −.12 | .54 | −.01 | −.01 |
| 15 | .23 | .32 | .26 | | .75 | .03 | −.08 | .28 | .45 | .14 | .07 |
| 16 | .08 | .18 | −.56 | .65 | | −.07 | .08 | .36 | .07 | .15 | .08 |
| 17 | .14 | .07 | .02 | −.10 | −.10 | | −.20 | −.15 | .03 | −.07 | .01 |
| 18 | −.11 | −.06 | −.26 | .09 | .12 | −.12 | | .08 | −.16 | .06 | .05 |
| 19 | −.01 | .18 | −.32 | .10 | .34 | −.16 | .23 | | −.30 | .11 | −.35 |
| 20 | −.22 | −.39 | −.15 | −.30 | −.14 | −.07 | .15 | −.08 | | .08 | .14 |
| 21 | | | | | | | | | | | .04 |
| 22 | | | | | | | | | | | |

* For $P = 0.05$, r = 0.17; for $P = 0.01$, r = 0.23.
† Physiological maturity right side of diagonal, drought left side of diagonal.

characters in the 1976 irrigated environment were smaller than in the 1976 nonirrigated environment. This suggests that there was less competition for soil moisture within the plants under nonstress conditions as discussed by Grafius and Thomas (1971), and that the genetic potential of most plant characters would be more fully expressed in a nonstress environment.

The association of harvest index with maturity and height was identical to the relationship found between seed yield and maturity; negative in the irrigated environments and positive in the nonirrigated. To reduce height of soybean lines genetically would probably lead to an increased harvest index, as has been noted in the semidwarf wheats (Singh and Stoskopf, 1971; Wallace and Munger, 1966). Height was correlated with harvest index in the nonirrigated environments suggesting that tall genotypes were vigorous, deep rooted plants, which were better able to obtain additional soil moisture during pod fill. Harvest index, with a correlation of 0.90 with seed yield in the 1976 nonirrigated environment (Table 4), was at an inefficient level, .19

Table 6. Interannual phenotypic correlations of soybean characters in various environment combinations (1975–1976).*

| Character | Average of combinations† | Irrigated 1975–1976 | Non-irrigated 1975–irrigated 1976 | Irrigated 1975–nonirrigated 1976 | Nonirrigated 1975–1976 |
|---|---|---|---|---|---|
| Seed yield | 0.08 | 0.39 | 0.21 | −0.16 | −0.13 |
| EGR | 0.02 | 0.33 | 0.06 | −0.11 | −0.20 |
| Biological yield | 0.20 | 0.38 | 0.38 | −0.03 | 0.02 |
| Growth rate | 0.08 | 0.27 | 0.25 | −0.06 | −0.14 |
| Harvest index | 0.08 | 0.40 | −0.09 | 0.04 | −0.05 |
| Seed weight | 0.56 | 0.81 | 0.65 | 0.17 | 0.44 |
| Maturity | 0.41 | 0.58 | 0.44 | 0.32 | 0.30 |
| Height | 0.50 | 0.60 | 0.47 | 0.46 | 0.47 |
| Seed quality | 0.18 | 0.21 | 0.45 | 0.03 | −0.01 |
| Seed mottling | 0.34 | 0.30 | 0.50 | 0.06 | 0.46 |
| Oil % | 0.33 | 0.37 | 0.37 | 0.39 | 0.19 |
| Protein % | 0.45 | 0.34 | 0.62 | 0.46 | 0.33 |
| Chemical constituents | 0.29 | 0.12 | 0.53 | 0.24 | 0.24 |

* For $P = 0.05$, $r = 0.23$; for $P = 0.01$, $r = 0.30$.
† The r values were averaged over environment combinations using Fisher's Z transformation.

(Table 7), according to Takeda and Frey (1976) and Wallace and Munger (1966).

Relationships between chemical traits, protein and oil content, in all environments were strongly negative, as has been previously observed (Johnson et al., 1955b; Weiss et al., 1952). In general protein was negatively correlated with characters that were positively associated with yield. Oil was positively associated with characters that were positively associated with yield. Chemical constituents (adding oil and protein percents together) was positively correlated with protein in all environments and negatively correlated with oil in both 1976 environments.

Poor seed quality was found to be associated with high protein content and large seed. Early-maturing lines had poorer seed quality than did late maturing lines, perhaps because temperatures were higher during early seed maturation (Feaster, 1949; Leffel, 1961). The mid- to late-summer drought of 1976 explains why mean seed quality differed between locations in 1976 and did not differ in 1975 (Table 7). High seed quality was correlated with EGR, growth rate, height, and seed yield.

Heritabilities for seed yield, EGR, biological yield, growth rate, harvest index, and EGR-fruiting period (Table 3) were lower than for other characters, similar to results reported previously (Anand and Torrie, 1963; Hanson and Weber, 1962; Johnson et al., 1955a; Mahmud and Kramer, 1951; Weber and Moorthy, 1952). Heritability for resistance to bacterial blight was estimated near zero in the nonirrigated environment and at 24.4% in

Table 7. Averaged agronomic performance and chemical composition of 360 lines in 1975 and 144 lines in 1976 in two environments.

| Character | 1975* | | 1976†‡ | |
|---|---|---|---|---|
| | Irrigated | Nonirrigated | Irrigated | Nonirrigated |
| Seed yield (kg/ha) | 3821 | 1647 | 3844 | 789 |
| EGR [(kg/ha)/day] | 25.9 | 12.3 | 26.0 | 6.1 |
| Biological yield (kg/ha) | 9199 | 3482 | 8350 | 3386 |
| Growth rate [(kg/ha)/day] | 62.0 | 26.1 | 56.4 | 27.0 |
| Harvest index (%) | .37 | .42 | .41 | .19 |
| Seed weight (grams/100 seeds) | 16.1 | 17.3 | 16.8 | 11.8 |
| Maturity (days) | 275 | 278 | 279 | 257 |
| Height (cm) | 113 | 60 | 118 | 81 |
| Seed quality (score) | 2.9 | 2.9 | 2.9 | 3.4 |
| Seed mottling (score) | 1.4 | 1.1 | 1.6 | 1.1 |
| Oil (%) | 20.5 | 20.4 | 21.3 | 19.5 |
| Protein (%) | 41.4 | 41.3 | 40.2 | 42.7 |
| Chemical constituents (%) | 61.9 | 61.7 | 61.5 | 62.2 |
| Shattering (score) | 1.3 | 1.2 | 1.7 | — |
| Lodging (score) | 2.8 | — | 3.0 | — |
| Early lodging (score) | 2.6 | — | — | — |
| First flower (days) | | | 181 | 180 |
| Last flower (days) | | | 232 | 223 |
| Length of flowering (days) | | | 50 | 43 |
| Bacterial blight (score) | | | 1.8 | 1.2 |
| Canopy shape (score) | | | 3.4 | 3.4 |
| EGR-fruiting period [(kg/ha)/day] | | | 83.0 | 22.7 |
| Physiological maturity (days) | | | 265 | — |
| Drought (score) | | | — | 2.0 |

* Location effect in 1976 significant at .05 level for all characters except canopy shape, chemical constituents, first day, last day, or length of flowering, and harvest index. Harvest index was significant at the .06 level.

† Random selections made in the 1974 irrigated or nonirrigated environment and grown in their environment of selection the following year.

‡ Selections from the irrigated and nonirrigated populations in 1975 grown in both environments in 1976.

the irrigated, indicating little genetic variation for resistance, low incidence of disease, or large error variance in the populations. Heritability estimates for most characters were higher when the soybean lines were evaluated in or selected from the irrigated rather than the nonirrigated environment. Greater genetic advance would be expected to result from selecting for most characters in an irrigated environment.

In the irrigated environment twenty-one of the 26 characters measured in 1976 were significantly correlated with the 1975 data, compared with only 11 of the traits in the nonirrigated environment (Table 6). Genotype response between location and years, as measured by correlation, indicated the 1975

Table 8. Phenotypic and genotypic correlation of soybean characters between irrigated and nonirrigated environments (1976).

| Trait | Phenotypic correlation* | Genotypic correlation |
|---|---|---|
| Seed yield | −0.08 | −0.24 |
| EGR | −0.01 | −0.28 |
| Biological yield | 0.02 | 0.07 |
| Growth rate | 0.08 | 0.28 |
| Harvest index | 0.07 | 0.16 |
| Seed weight | 0.35 | 0.60 |
| Maturity | 0.51 | 0.73 |
| Height | 0.46 | 0.76 |
| Seed quality | 0.17 | 0.30 |
| Seed mottling | 0.51 | 0.84 |
| Oil % | 0.54 | 0.72 |
| Protein % | 0.46 | 0.58 |
| Chemical constituents | 0.31 | 0.46 |
| First flower | 0.63 | 0.92 |
| Last flower | 0.45 | 1.22 |
| Length of flowering | 0.41 | 1.28 |
| Bacterial blight | 0.12 | — |
| Canopy shape | 0.46 | 0.88 |
| EGR-fruiting period | 0.02 | 0.05 |

* For $P = 0.05$, $r = 0.17$; for $P = 0.01$, $r = 0.23$.

nonirrigated environment more closely resembled the 1976 irrigated than the 1976 nonirrigated environment because of the extreme drought experienced in 1976. For the irrigated environment (both years) seed yield, EGR, biological yield, and growth rate were very strongly correlated compared with the three other environments. Our results agree with those of Green et al. (1971) and Schutz and Bernard (1967), who reported that seed quality is strongly affected by environment. Stability of environments between years did result in progeny characteristics more closely resembling those of their progenitors as previously reported (Johnson et al., 1955a; Mahmud and Kramer, 1951).

As noted in Table 8, even though the two 1976 environments were diverse, we obtained significant phenotypic correlations and strong genotypic correlations for many characters, indicating that genetic advance can be obtained by selecting for these characters even in the severe droughty nonirrigated environment.

To improve seed yield, plant breeders can make greater progress by selecting for growth rate or biological yield than for harvest index. Since protein content and seed yield are negatively correlated, special attention should be paid to keep yields constant in a program of selection for higher protein content. Because of the negative association of yield and maturity

date in an irrigated environment, genotypes should be compared with cultivars adapted to nonirrigated production of similar maturity to facilitate selection. With increased interest in producing soybeans under irrigation, selection should be practiced for genotypes that mature earlier than those grown in surrounding nonirrigated environments. Estimates of heritability were greater in the irrigated environment or for soybean populations selected from the irrigated environment indicating greater progress from selection can be expected in the irrigated environment. Interannual correlations indicated that seed quality was as affected by environmental differences as were yield and other yield related characters. Plants undergoing maturation during hot, dry periods produced seed of low quality. Interannual correlations also indicated there was greater phenotype stability in the irrigated environment, thus inferior plant types should be eliminated more easily in the more favorable environment.

## Literature Cited

Anand, S. C., and J. H. Torrie. 1963. Heritability of yield and other traits and interrelationships among traits in the $F_3$ and $F_4$ generations of three soybean crosses. Crop Sci. 3:508–511.

Byth, D. E., C. R. Weber, and B. E. Caldwell. 1969. Correlated truncation selection for yield in soybeans. Crop Sci. 9:699–702.

Feaster, C. V. 1949. Influence of planting date on yield and other characteristics of soybeans grown in Southeastern Missouri. Agron. J. 41:57–62.

Fischer, R. A., and Z. Kertesz. 1976. Harvest index in spaced populations and grain weight in microplots as indicators of yielding ability in spring wheat. Crop Sci. 16:55–59.

Grafius, J. E. 1966. Directed effects of environment on populations of small grain varieties. Crop Sci. 6:269–271.

Grafius, J. E., and R. L. Thomas. 1971. The case for indirect genetic control of sequential traits and the strategy of deployment of environmental resources by the plant. Heredity 26:433–442.

Green, D. E., V. D. Luedders, and B. J. Moraghan. 1971. Heritability and advance from selection for six soybean seed-quality characters. Crop Sci. 11:531–533.

Hanson, W. D., and C. R. Weber. 1962. Analysis of genetic variability from generations of plant-progeny lines in soybeans. Crop Sci. 2:63–67.

Johnson, H. W., H. F. Robinson, and R. E. Comstock. 1955a. Estimates of genetic and environmental variability in soybeans. Agron. J. 47:314–318.

Johnson, H. W., H. F. Robinson, and R. E. Comstock. 1955b. Genotypic and phenotypic correlations in soybeans and their implications in selection. Agron. J. 47:477–483.

Kwon, S. H., and J. H. Torrie. 1964. Heritability of and interrelationships among traits of two soybean populations. Crop Sci. 4:196–198.

Leffel, R. C. 1961. Planting data and varietal effects on agronomic and seed compositional characters in soybeans. Maryland Agr. Exp. Sta. Bull. A–117.

Mahmud, I., and H. H. Kramer. 1951. Segregation for yield, height, and maturity following a soybean cross. Agron. J. 43:605–609.

Rosielle, A. A., and K. J. Frey. 1975. Estimates of selection parameters associated with harvest index in oat lines derived from a bulk population. Euphytica 24:121–131.

Schutz, W. M., and R. L. Bernard. 1967. Genotype x environment interactions in the regional testing of soybean strains. Crop Sci. 7:125–130.

Singh, I. O., and N. C. Stoskopf. 1971. Harvest index in cereals. Agron. J. 63:224–226.

Takeda, K., and K. J. Frey. 1976. Contributions of vegetative growth rate and harvest index to grain yield of progenies from *Avena sativa* × *A. sterilis* crosses. Crop Sci. 16:817–821.

Wallace, D. H., and H. M. Munger. 1966. Studies of the physiological basis for yield differences. II. Variations in dry matter distribution among aerial organs for several dry bean varieties. Crop Sci. 6:503–507.

Weber, C. R., and B. R. Moorthy. 1952. Heritable and nonheritable relationships and variability of oil content and agronomic characters in the $F_2$ generation of soybean crosses. Agron. J. 44:202–209.

Weber, C. R., L. R. Empig, and J. C. Thorne. 1970. Heterotic performance and combining ability of two-way $F_1$ soybean hybrids. Crop Sci. 10:159–160.

Weiss, M. G., C. R. Weber, L. F. Williams, and A. H. Probst. 1952. Correlation of agronomic characters and temperature with seed compositional characters in soybeans as influenced by variety and time of planting. Agron. J. 44:289–297.

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# Population Decrease and Change in Nonmetropolitan Kansas*

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ABSTRACT

This paper analyzes the differences between natural-increase and natural-decrease counties in nonmetropolitan counties of Kansas. The results indicate that sustained net out-migration is the dominant factor contributing to natural decrease. But low fertility also contributed to natural decrease in that the counties with sustained net out-migration were age-selective; that is, young adults of reproductive age moved elsewhere. Analyzing the sustenance organization of counties revealed that natural-increase counties were supported mainly by capital-intensive agriculture and service center economies; and that natural-decrease counties were composed mainly of family farms. In nonmetropolitan counties in which manufacturing was important, population experienced both natural increase and decrease. Furthermore, contrary to previous findings, 35 percent of the counties differed between their natural increase-decrease status and their absolute growth-decline status when migration was added to the analysis. The data for this study were obtained from state and national population censuses and vital statistics.

Natural decrease of population has not been studied extensively since the early 1970s, when nonmetropolitan growth was becoming noticeable. In the United States between 1970 and 1975 2.3 million people moved into nonmetropolitan counties; in comparison 3 million moved out of these counties in the 1960 decade (Biggar, 1979). "Rural resurgence" has not contributed to nonmetropolitan growth in all regions of the United States; it has been occurring mainly in counties that can be classified as retirement counties, military counties, university counties, counties adjacent to SMSAs**, primary-industry-boom-counties, and counties in mainly these regions: the

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** Standard Metropolitan Statistical Area.

Upper Great Lakes, the Ozarks, South Appalachia, Northern New England, and Rocky Mountains-Utah Valleys (Morrison and Wheeler, 1976).

The center of the United States—the Great Plains, has not experienced the same nonmetropolitan turnaround as other regions. As Morrison (1978) has stated, because fertility is low in the United States, population in some counties increases at the expense of population decreases in other counties. The counties losing population via net out-migration are not only those containing inner cities of the largest SMSAs but also those classed as nonmetropolitan.

Dorn (1939) found that in 1935 and 1936 there were natural-decrease counties and cities in all geographic regions of the United States and that in 255 different-sized places deaths exceeded births. Beale (1964), who investigated rural depopulation from 1950 to 1960 in state economic areas in the U.S., found in that decade out-migration was heavy in the agricultural sphere, due mainly to mechanization. Out-migration resulted in an uneven age structure and, in turn, deaths exceeded births in many counties during the peak of the post-war baby boom. Beale noted there were two principal concentrations of natural-decrease counties: (1) the southern fringe of the Corn Belt (in southern Iowa, northern and western Missouri, and eastern Kansas); and (2) Texas and part of Oklahoma.

In a more recent study, Chang (1974) investigated natural decrease in Iowa counties for 1966–1970 by analyzing the role that migration and fertility played in bringing about an excess of deaths over births. Chang (1974:668) concluded that:

> Net out-migration clearly was a dominant factor in bringing about natural decrease in Iowa. Because out-migrants were predominently young adults, the age structure of natural-decrease counties became highly distorted, death rates in these counties reached a level too high to be compensated for through reproduction.
>
> Fertility, although secondary to its relationship to natural decrease, was doubtlessly a contributing factor to the occurrence of the condition in Iowa counties because the natural-decrease counties were consistently lower in fertility than any other county group.

Dorn, Beale, and Chang all studied natural decrease; their emphases, however, were different. Dorn, whose research was in the low fertility depression years, based his explanation of natural decrease on declining fertility throughout the U.S. since 1800. Beale, whose research was during the high-birth period of the post-war baby boom, emphasized the distorted age structure of natural-decrease counties due to age-selective net out-migration. Chang, whose study period (1966–1970) was one of low fertility and high mobility, emphasized both migration and fertility, noting that Dorn's and Beale's studies differed due to their time-specific demographic histories.

Thus, the effects of both fertility and migration on natural decreases in population need to be considered.

However, changing demographic components do not occur in a vacuum. Human ecologists and others have claimed that sustenance organization[1] directly influences fertility, mortality, and migration in order to achieve a balance between population size and life chances (Frisbie and Poston, 1978). Therefore, the relationship between sustenance organization and population change will be included in this investigation.

Because natural decrease of population in nonmetropolitan areas does not seem to be disappearing even in a time of nonmetropolitan growth, it is essential to examine the phenomenon periodically. The purpose of this study was: (1) to identify and describe natural-increase and natural-decrease nonmetropolitan counties in Kansas; (2) to investigate the components of population change (fertility, mortality, and migration) to assess the role each plays in producing an excess of deaths over births in nonmetropolitan Kansas counties; (3) to assess the sustenance organization of nonmetropolitan Kansas counties that contribute to demographic and social change (and, thus, to the well-being of the nonmetropolitan population of Kansas); and (4) analyze natural decrease-increase in relation to absolute growth and decline.

By identifying and interpreting population change and some of its causes as patterns of or changing patterns of sustenance organization, a clearer understanding of an area (as nonmetro Kansas) could greatly add to the current and future needs of the population.

## METHODS

The substantial flow of Kansans to other states during the twentieth century has had a serious depressing effect on the state's population growth. For example, four-fifths of the counties had reached their peak population by 1950 or in prior decades (28 counties peaked in 1900 or earlier).

During the three-year study period, 1974–1976, ninety-eight of the state's 105 counties were considered nonmetropolitan; the remaining seven counties are part of metropolitan areas. Because of the diverse sociological and demographic characteristics of metro and nonmetro areas, only the nonmetro counties were included in this study. Also, nonmetro areas have been/are the focus of much research due to demographic, economic, and sociological changes during the past decade.

The 98 nonmetro counties of Kansas were classified according to differ-

[1] Sustenance organization can be simply defined as the pattern of economic activities and is composed of sustenance activities. Browning and Gibbs (1971:233-34) defined sustenance activity as any "expenditure of human energy in the direct pursuit of food or in the production of some good or services."

ences between births and deaths. These counties in which the average number of births exceeded the average number of deaths during 1974 through 1976 were termed natural-increase counties. Conversely, those counties in which the average number of deaths exceeded the average number of births were termed natural-decrease counties. In the definition migration was not considered; hence, absolute population gains or losses were not implied. Natural-increase counties could have an absolute loss of population if net out-migration exceeds the natural increase; and, natural-decrease counties could have an absolute gain if net in-migration exceeds natural decrease. However, as evidenced in the studies by Beale and Chang, absolute gains or losses closely approximate the path of natural increase or natural decrease. In the last part of the analysis, net migration was taken into consideration in order to compare absolute growth-decline and natural increase-decrease. The chi-square test was used in order to determine if any significant differences exist between the population types and demographic indicators.

*Definitions.* Counties were classified into three groups: high natural increase, low natural increase, and natural decrease, described as follows:

(1) High natural-increase counties (HNI) are those in which the birth–death ratio is greater than the state's average nonmetropolitan birth–death ratio for the three years (1974–1976). The state's nonmetro birth–death ratio was 1.321 births per 1.00 death. All counties with a birth–death ratio of 1.322 or greater were considered high natural-increase: 31 counties were in this group.

(2) Low natural-increase counties (LNI) are counties in which the birth–death ratio is below the nonmetro state average but the average number of births exceeded the average number of deaths for the 1974–1976 period. Thus, counties with an average birth–death ratio of 1.00 to 1.321 births per 1.00 death were considered low natural-increase; that included 23 counties.

(3) Natural-decrease counties (ND)—those in which the number of deaths exceeded the number of births for the three-year period (a birth–death ratio of less than 1.00). This group includes 44 counties.

To better understand the population dynamics of nonmetropolitan Kansas, this study utilizes a sustenance organization (the pattern of economic activities) and differentiation (differences among members of a population in their sustenance activities) scheme in describing the basic economic structure of counties developed by Jan and Cornelia Flora (1978). Since population change molds itself to the availability of opportunities and resources it is necessary to include their relationship. The measures of sustenance organization are described as follows:

(1) Capital Intensive Agriculture (CIA)—20 counties.

a. The type of agriculture practiced in the CIA counties is large-scale and capital-intensive rather than family-size farming. There is a high value of

sales of agricultural products per farm (58 percent of sales were from farms with annual sales exceeding $80,000, as opposed to the average of 33 percent for all Kansas counties), and a high expenditure for hired labor per farm. Most CIA counties have a relatively large percentage of cropland under irrigation.

b. These counties had an above-average proportion of their labor force in agriculture in 1970. Associated with that was a lower-than-average score on complexity of commercial, professional, governmental, and other services available in the county (low differentiation), and a lower percentage of the labor force employed in manufacturing than was true for the average Kansas county.

(2) Family Farm (FF)—46 counties.

a. In these counties the proportion of the labor force in agriculture in 1970 was above average. Associated with that was a much lower-than-average score in complexity of commercial, professional, governmental, and other services available in the county (low differentiation), and a lower percentage of the labor force employed in manufacturing than was true for the average Kansas county.

b. The type of agriculture practiced in the FF counties is family-sized rather than large-scale capital-intensive. It is characterized by a moderate value of sales and agricultural products per farm (only 23 percent of sales were from farms with more than $80,000 in annual sales, as opposed to the average 33 percent for all Kansas counties) and by low expenditure for hired labor per farm. Most of the FF counties have little irrigation.

(3) Nonmetropolitan Manufacturing (NMM)—15 counties.

a. A large proportion of the work force is in manufacturing; score on complexity of commercial, professional, governmental, and other services available in the county (differentiation) is above average; and a relatively small proportion of the labor force is in agriculture.

b. Employment in the service sector is average.

c. Family-farm agriculture predominates over capital-intensive agriculture (the latter defined in terms of large farms with substantial amounts of hired labor).

(4) Service Center (SC)—17 counties.

a. A large proportion of the work force is employed in the tertiary or service sector, including employment in local, state or federal government, in educational or health institutions.

b. A high degree of complexity exists in types of commercial, professional, governmental and other services offered in the county, while a relatively small proportion of the labor force is in agriculture.

Population census reports and vital statistics for the United States and the State of Kansas were the primary data sources used in this study.

Table 1. Sustenance organization by natural increase-decrease classification groups: Nonmetro Kansas counties, 1974–1976.*

| Sustenance organization | All non-metro counties (N = 98) | County classification: Natural decrease (N = 44) | Natural increase: Total (N = 54) | Natural increase: Low (N = 23) | Natural increase: High (N = 31) |
|---|---|---|---|---|---|
| CIA | 20 (100.0) | 4 (20.0) | 16 (80.0) | 1 | 15 |
| FF | 46 (100.0) | 30 (65.2) | 16 (34.8) | 14 | 2 |
| NMM | 15 (100.0) | 7 (46.7) | 8 (53.3) | 5 | 3 |
| SC | 17 (100.0) | 3 (17.6) | 14 (82.4) | 3 | 11 |

* Numbers in parentheses are the percentages in the natural decrease and total natural increase categories.
Source: Kansas Department of Health and Environment, 1974–1976; Flora and Flora, 1978.

## Findings

Table 1 shows county classifications by sustenance organization. Forty-four (44.9 percent) of the 98 nonmetro counties were natural-decrease counties for the period 1974–1976. Clearly FF counties contributed most to natural decrease, in that 30 of the 46 were natural decrease (65.2 percent). The vast majority of CIA and SC counties were natural increase counties (and high natural increase, see Table 1). The NMM counties were fairly even (eight natural-increase, seven natural-decrease). Five of the eight NMM natural-increase counties, however, were adjacent to an SMSA, and six of the seven natural-decrease NMM counties were nonadjacent. The relationship between natural-increase NMM counties and metropolitan adjacency seems to be positive.

In 1976 Kansas was approximately 66 percent urban, compared with

Table 2. Percentage of population aged 65 and over for Kansas nonmetropolitan counties, by county classification groups: 1976.

| Population aged 65 and over | All non-metro counties (N = 98) | County classification: Natural decrease (N = 44) | Natural increase: Total (N = 54) | Natural increase: Low (N = 23) | Natural increase: High (N = 31) |
|---|---|---|---|---|---|
| Less than 14% | 27.6% | — | 50.0% | — | 87.1% |
| 14.0–17.9% | 28.6 | 15.9 | 38.9 | 73.9 | 12.9 |
| 18.0–20.9% | 24.4 | 40.9 | 11.1 | 26.1 | — |
| 21.0 and over | 19.4 | 43.2 | — | — | — |
| | 100.0 | 100.0 | 100.00 | 100.0 | 100.0 |
| Median | 17.5 | 20.45 | 13.85 | 16.90 | 10.50 |

Note: $\chi^2 = 115.81$, df = 6, $P < .001$.
Source: National Clearing House on Aging, 1978.

Table 3. Rate of net migration for Kansas nonmetropolitan counties by county classification groups: 1970–1975.

| Rate of net migration | All non-metro counties (N = 98) | County classification: Natural decrease (N = 44) | Natural increase: Total (N = 54) | Natural increase: Low (N = 23) | Natural increase: High (N = 31) |
|---|---|---|---|---|---|
| −10.00 and over | 9.2% | 6.8% | 11.1% | 8.7% | 12.9% |
| −5.00 to −9.99 | 18.4 | 18.2 | 18.5 | 21.7 | 16.1 |
| Less than −5.00 | 26.5 | 31.8 | 22.2 | 34.8 | 12.9 |
| Less than 5.00 | 21.4 | 18.2 | 24.1 | 21.7 | 25.8 |
| 5.00 to 9.99 | 17.3 | 18.2 | 16.7 | 4.4 | 25.8 |
| 10.00 and over | 7.2 | 6.8 | 7.4 | 8.7 | 6.5 |
| | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Median | −0.777 | −2.488 | −0.691 | −2.469 | 0.640 |

Note: $\chi^2 = 8.33$, df = 10, $P > .05$.
Source: U.S. Bureau of the Census, 1978.

about 74 percent for the United States. In nonmetropolitan Kansas, however, 47 of the 98 counties did not have an urban place of 2500 people or more, and there were only four places of 25,000 to 49,999. The majority of the Kansas population in 1976 was nonmetropolitan; 56.9 percent resided in the 98 nonmetropolitan counties.

The county classifications varied according to population size. The ND counties, constituting 45 percent of the nonmetropolitan counties, had only 35 percent of the total nonmetro population. The natural-increase counties made up 55 percent of the counties and 65 percent of the nonmetro population. The HNI counties represented 32 percent of all nonmetro counties and 45 percent of the population; the LNI counties, 24 percent of the counties and 20 percent of the population.

An indicator that closely depicts the demographic structure of a population is age. Table 2 shows the highly significant relationship between county classifications and the population aged 65 and over. In 43.2 percent of the natural-decrease counties in 1976, 21 percent or more of the population was aged 65 and older, whereas no natural-increase county recorded 21 percent or more of its population aged 65 and over. The county-classification medians indicated that 20.45 percent of ND counties and only 13.85 percent of the natural-increase counties had populations aged 65 and older.

Residents of natural-increase counties were younger in age, as measured by percentage of the population aged 65 and older (also by median age of each county classification: HNI—28.4 years; LNI—33.8 years; and, ND—38.6 years). Also they were more heavily involved in capital-intensive agriculture and service-center economies than were residents in the natural-decrease counties.

Table 4. Rate of net migration for Kansas nonmetropolitan counties, by county classification groups: 1976.

| Rate of net migration | All non-metro counties (N = 98) | County classification: Natural decrease (N = 44) | Natural increase: Total (N = 54) | Natural increase: Low (N = 23) | Natural increase: High (N = 31) |
|---|---|---|---|---|---|
| −10.00 and over | 28.6% | 31.8% | 25.9% | 21.7% | 29.0% |
| −5.00 to −9.99 | 7.1 | 9.2 | 5.6 | 4.3 | 6.5 |
| Less than −5.00 | 12.2 | 13.6 | 11.1 | 13.2 | 9.7 |
| Less than 5.00 | 14.3 | 15.9 | 13.0 | 8.7 | 16.1 |
| 5.00 to 9.99 | 9.2 | 6.8 | 11.1 | 21.7 | 3.2 |
| 10.00 and over | 28.6 | 22.7 | 33.3 | 30.4 | 32.5 |
| | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Median | 1.281 | −1.780 | 3.813 | 5.811 | 2.698 |

Note: $\chi^2 = 8.44$, df = 10, $P > .05$.
Source: Kansas Department of Health and Environment, 1976.

*Migration and natural decrease.* Beale (1969) and Chang (1974) found that age-selective migration was the primary factor causing natural decrease. Young adults, of reproductive age, move for economic opportunities, thus the counties not only lose them but also their future generations—which can be called the "momentum of natural population decrease." Such migration has occurred in Kansas since the beginning of this century, but the greatest loss was during the 1960s. Out-migration tends to affect age structure by aging the population, as seen in Table 2, and the median age of those in each county group. Table 3 shows the rate of net migration for nonmetropolitan counties from 1970 to 1975. Although county-group differences were not significant as determined by the chi-square test, the only group that had a positive rate of net migration was the HNI group. The ND group median was −2.488, compared with −0.691 for the natural-increase counties. That indicates the ND counties were affected more by net out-migration than were the natural-increase counties.

In 1974, for the first time in more than 60 years, net in-migration in Kansas was substantial. Though most of the increase was in metropolitan areas, net in-migration in the nonmetropolitan counties amounted to about 3600 persons between 1974 and 1976. Table 4 illustrates the rate of net migration for 1976, the last year of the analysis. Although not statistically significant, a nonmetropolitan turnaround was evident, compared with the 1970–1975 rate of net migration. The median rate of net migration was positive for all 98 nonmetro counties. Change was dramatic in the LNI counties; in turn, the total natural-increase group was positive (and thus, all 98 counties). Also, the median for ND counties decreased from −2.488 for the 1970–1975 period

Table 5. Crude death rate for Kansas nonmetropolitan counties by county classification groups: 1974–1976.

| Crude death rate | All non-metro counties (N = 98) | County classification: Natural decrease (N = 44) | Natural increase: Total (N = 54) | Natural increase: Low (N = 23) | Natural increase: High (N = 31) |
|---|---|---|---|---|---|
| Less than 10.00 | 32.7% | — | 59.3% | 17.4% | 90.3% |
| 10.00 to 13.99 | 38.8 | 38.6 | 38.9 | 78.3 | 9.7 |
| 14.00 and over | 28.5 | 61.4 | 1.8 | 4.3 | — |
| | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Median | 12.26 | 14.18 | 8.92 | 11.77 | 7.12 |

Note: $\chi^2 = 93.74$, df = 4, $P < .001$.
Sources: Kansas Department of Health and Environment, 1974–1976; U.S. Bureau of the Census, 1978.

to −1.780 in 1976. The greatest difference was in the LNI group: from −2.469 during 1970–1975 to +5.811 in 1976.

Observations on Kansas during the 1960s and early 1970s are similar to Beale's (1969) and Chang's (1974) observations. The middle 1970s appeared to be the exception rather than the rule, in that nonmetro Kansas counties then began experiencing substantial in-migration for the first time in this century.

*Mortality and natural decrease.* In natural-decrease counties, older-age structure coincided with higher-than-average death rates. Table 5 demonstrates a significant relationship between crude death rates and county classifications for 1974–1976. Table 5 indicates that no natural-decrease county had a crude death rate of less than 10.0 per 1000 population, whereas 59.3 percent of the natural-increase counties had crude death rates of less than 10.0 per thousand. The median crude death rate for ND counties was significantly greater than that of the natural-increase counties (14.18 versus 8.92, respectively), and twice as great as that of the HNI counties (14.18 versus 7.12, respectively).

The positive relationship between natural decrease and the crude death rate certainly reflected changes in age structure of residents of natural-decrease counties. Higher mortality was a consequence, rather than a cause of, natural population decrease resulting from the distorted age structure caused by out-migration and low fertility.

*Fertility and natural decrease.* Chang (1974:663) found that lower fertility was associated more with natural decrease counties than with any other county group. Three fertility measures were utilized for the middle year of the analysis—1975. (1) General fertility rate—GFR = $(B/P^f_{15-44}) \times 1000$, where B is the number of live births during 1975 and $P^f_{15-44}$ is the number of females aged 15 to 44 in the same year; (2) Total fertility rate—

$TFR = \left(5 \sum_{i=1}^{6} B_i/P_i\right) \times 1000$, where $B_i$ is the number of live births to mothers of age group i (five-year age groups 15 to 44) registered during the year and $P_i$ is the 1975 population of women of the same age category; and (3) the replacement index (explained in the footnote of Table 7).

The GFR revealed a highly significant relationship with the natural-decrease counties having a lower rate than any other county group (Table 6). Only 4.7 percent of the ND counties had a GFR greater than 85, compared with 31.5 percent for natural increase counties.

The TFR also revealed a highly significant relationship with the ND county group having the lowest rate of any other group. More than 24 percent of the natural-increase counties had a TFR of 2500 or greater, compared to only 4.5 percent of the ND counties. The surprising finding was that nonmetro Kansas as of 1975 was barely replacing itself as measured by the (mean) replacement index (102.3); the ND counties were well below replacement (95.7) and the HNI group fertility level was only 10.8 percent higher than general replacement. In fact, the mean TFR range was quite small between the ND and HNI counties (just under 2 children per woman to nearly 2.3 children per woman, respectively).

These data agreed with the findings of Chang (1974) that fertility was lower in natural-decrease counties than in natural-increase counties. However, Chang (1974:665) stated that ". . . it would be inaccurate to say that natural population decrease in . . . counties was due to inadequate fertility." He found ND counties had a fertility level 24.4 percent greater than generational replacement in Iowa for 1970. This was not the case in nonmetro Kansas. Fertility levels were below generational replacement in the ND county group and barely above generational replacement in the natural-increase counties. It appears that low fertility was having a larger impact on natural decrease than observed previously (at least in the 1970s).

*Absolute growth and natural decrease.* In that natural decrease or increase does not describe population change in absolute terms, this section examines the county classifications in terms of all three population processes (births, deaths, and net migration).

After 1970, a population reversal has been occurring, that is, metropolitan areas are losing population and nonmetropolitan areas are gaining population. Even though natural decrease is occurring in some areas of the U.S. simultaneously with the so-called "reversal" or "turnaround," it is important to analyze both types of population change in this seemingly transitional period. Current natural-decrease counties could be growing due to net-in-migration and vice versa. Prior to 1970 when the migration pattern in the U.S. was of the rural-urban type, natural decrease was usually observed in the absence of migration. Natural decrease is still occurring at the same

time as nonmetro growth which makes migration an integral part of the growth process. Therefore, absolute growth and natural growth are compared in this section.

Absolute growth was calculated as follows:

$$\frac{\text{Births}(1974\text{–}76) - \text{Deaths}(1974\text{–}76) + \text{Net Migration}(1974\text{–}76)}{\text{1974 Population}} \times 1000$$

The three categories of absolute growth/decline are described as follows:

(1) High absolute increase counties (HAI)—those that have a rate greater than the mean for all absolute increase counties. The absolute increase county mean increase was 33.79 per 1000 population. Eighteen counties had a rate of 33.8 or greater.

(2) Low absolute increase counties (LAI)—those that have a rate equal to or less than the mean for all absolute increase counties but greater than zero. Thirty-two counties had a rate of 33.79 or less but greater than zero.

(3) Absolute decrease counties (AD)—those counties in which a negative rate was recorded. Forty-eight counties resulted in a rate of less than zero.

Table 8 shows the absolute increase-decrease classification by sustenance organization. The relationship between county classifications (natural increase-decrease and absolute increase-decrease) was close in aggregate terms; 54 natural-increase counties and 44 natural-decrease counties, compared with 50 absolute growth and 48 absolute decline counties. However, there were "cross-over" differences. That seemingly small difference of four counties actually involved 34 counties (35 percent of all nonmetro counties); nineteen natural-increase counties had absolute declines due to the effects of net out-migration, and fifteen natural decrease counties experienced absolute increase due to net in-migration.

Comparing Tables 1 and 8 one can see the difference due to net migration. The FF counties contributed most to absolute-decrease with 31 of the 46 counties recording absolute decline (similar to natural decrease). The SC counties were also similar in the absolute and natural growth decline status. The CIA and NMM counties changed quite a bit from one growth measure to the other. Eighty percent of the CIA counties were natural increase, but 50 percent were absolute increase; thus, CIA counties experienced out-migration during the 1974–1976 period. Similarly, 53 percent of NMM counties were natural increase and 80 percent absolute increase due to net in-migration.

Table 9 presents the "cross-over" counties by sustenance activity. Thirty-seven percent of the FF counties and 18 percent of the SC counties changed population status. These two sustenance types were nearly equal in their distributions. That is, eight FF counties were natural decrease with

Table 6. General fertility rate for nonmetropolitan Kansas counties by county classification groups: 1975.

| General fertility rate | All non-metro counties (N = 98) | County classification | | | |
|---|---|---|---|---|---|
| | | Natural decrease (N = 44) | Natural increase | | |
| | | | Total (N = 54) | Low (N = 23) | High (N = 31) |
| Less than 65 | 23.7% | 25.6% | 22.2% | 26.1% | 19.3% |
| 65–74 | 35.2 | 53.5 | 20.4 | 26.1 | 16.1 |
| 74–84 | 22.5 | 16.3 | 25.9 | 34.8 | 19.4 |
| 85 and over | 19.6 | 4.7 | 31.5 | 13.0 | 45.2 |
| | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Median | 72.0 | 69.1 | 77.4 | 74.7 | 80.7 |

Note: $\chi^2 = 26.46$, df = 6, $P < .001$.
Sources: Kansas Department of Health and Environment, 1975; National Cancer Institute, 1978.

Table 7. Total fertility rate and replacement index for nonmetropolitan Kansas counties by county classification groups: 1975.[a]

| Total fertility rate | All non-metro counties (N = 98) | County classification | | | |
|---|---|---|---|---|---|
| | | Natural decrease (N = 44) | Natural increase | | |
| | | | Total (N = 54) | Low (N = 23) | High (N = 31) |
| Less than 2000 | 39.8% | 52.3% | 29.6% | 26.1% | 32.3% |
| 2000–2499 | 44.9 | 43.2 | 46.3 | 69.6 | 28.9 |
| 2500–2999 | 13.3 | 4.5 | 20.4 | 4.3 | 32.3 |
| 3000 and over | 2.0 | — | 3.7 | — | — |
| | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| Mean | 2118.3 | 1985.7 | 2226.4 | 2137.0 | 2292.7 |
| Mean replacement index | 102.3 | 95.7 | 107.6 | 103.2 | 110.8 |
| Median | 2060.7 | 1992.3 | 2151.8 | 2150.1 | 2342.6 |
| Median replacement index | 99.6 | 96.2 | 104.0 | 103.9 | 113.2 |

Note: $\chi^2 = 24.79$, df = 6, $P < .001$.
Sources: Kansas Department of Health and Environment, 1975; National Cancer Institute, 1978.

[a] The replacement index in this table was computed by dividing the mean and median total fertility rate by a national replacement quota of 2070 and by expressing the result on a percentage basis. A replacement index of 120 means that women had borne children at a rate that would increase the population by 20 percent per generation.

The replacement index was calculated for both the mean and median total fertility rate. The median was used throughout this study, but does not adequately depict real replacement of the total fertility rate. The replacement index based on the median for all 98 counties was 99.6 which is below replacement. This was misleading because the 98 nonmetropolitan counties were actually above replacement (102.3) when the mean was used to measure replacement.

Table 8. Sustenance organization by absolute increase-decrease classification groups: Nonmetro Kansas counties, 1974–1976.*

| Sustenance organization | All non-metro counties (N = 98) | County classification: Absolute decrease (N = 48) | Absolute increase: Total (N = 50) | Absolute increase: Low (N = 32) | Absolute increase: High (N = 18) |
|---|---|---|---|---|---|
| CIA | 20 (100.0) | 10 (50.0) | 10 (50.0) | 6 | 4 |
| FF | 46 (100.0) | 31 (67.4) | 15 (32.6) | 12 | 3 |
| NMM | 15 (100.0) | 3 (20.0) | 12 (80.0) | 8 | 4 |
| SC | 17 (100.0) | 4 (23.5) | 13 (76.5) | 6 | 7 |

* Numbers in parentheses are the percentages in the absolute decrease and total absolute increase categories.
Sources: Kansas Department of Health and Environment, 1974–1976; Flora and Flora, 1978.

absolute increase and nine were natural increase with absolute decline. Similarly, one SC county experienced natural decrease with absolute increase: and, two experienced natural increase with absolute decline.

The CIA and NMM counties were not nearly equal in their distribution. Only one CIA county (45 percent of the CIA counties were cross-over counties) experienced natural decrease with absolute increase. However, eight counties recorded natural increase with absolute decrease, thus CIA "cross-over" counties have experienced substantial out-migration during the 1974–1976 period. The reverse is true for the NMM counties. All five "cross-over" counties (one-third of all NMM counties) were of the natural decrease-absolute increase type, and therefore experienced net in-migration.

Table 9. Cross-over counties by type and sustenance organization: Nonmetro Kansas counties, 1974–1976.

| Sustenance organization | Cross-over types: Natural decrease with absolute increase (net in-migration) Col. 1 | Natural increase with absolute decrease (net out-migration) Col. 2 | Low NI* with absolute decrease (net in-migration) Col. 3 | High NI* with absolute decrease (net out-migration) Col. 4 |
|---|---|---|---|---|
| CIA (9) | 1 | 8 | — | 8 |
| FF (17) | 8 | 9 | 7 | 2 |
| NMM (5) | 5 | — | — | — |
| SC (3) | 1 | 2 | 1 | 1 |
| Total (34) | 15 | 19 | 8 | 11 |

* Natural increase.
Numbers in parentheses are the number of counties in each category.
Column 2 (Natural increase counties) = Column 3 (Low natural increase counties) + Column 4 (High natural increase counties).
Sources: Kansas Department of Health and Environment, 1974–1976; Flora and Flora, 1978.

There appears to be a pattern of growth status. Although the number of counties in each of the two cross-over categories are not markedly different (15 natural decrease-absolute increase; and 19 natural increase-absolute decrease), there appears to be variation by county sustenance activity. CIA cross-over counties have high natural increase with enough out-migration to record absolute decrease. NMM cross-over counties have natural decrease with enough in-migration to record absolute increase.

Chang's (1974:659) statement that ". . . the pattern of (absolute) gains or losses, however, follows closely the pattern of natural increase or decrease" appears to be accurate only in aggregate terms of comparing county levels of natural increase or decrease and absolute growth or decline. His statement does not appear to be accurate (at least for Kansas), however, if one analyzes the number of counties involved in the "cross-over"—that is, the number of natural-decrease counties with absolute growth and natural-increase counties with absolute decline. In this research when observing both county population growth classifications, there is an inconsistent pattern for 34 of the 98 nonmetropolitan counties (nearly 35 percent).

There appears to be a "demographic lag" that results from what I earlier termed the "momentum" of natural population decrease. Though natural-decrease counties with absolute gains were experiencing net in-migration during 1974 through 1976, this recent in-migration has not yet turned around the birth–death ratios so that natural population increase can be recorded. Conversely, though natural-increase counties with absolute declines experienced net out-migration, perhaps it has not been large enough or long enough in duration to cause natural decrease to be recorded. One essential factor not taken into consideration here (and one difficult to account for during intercensal periods) was age structure of counties and age structure of migrants. Natural population increase may never be recorded for natural-decrease counties with absolute gains resulting from in-migration if the in-migrants are older, for example those moving in for retirement. Conversely, natural population increases may continuously be recorded for natural-increase counties with absolute declines resulting from out-migration if the out-migrants are older and moving out for retirement. These examples are called "demographic recomposition" by McCarthy and Morrison (1979).

Without knowing the age of migrants and without analyzing both natural increase and natural decrease, along with absolute growth of analytical units, we cannot understand fully the importance of population change which is becoming increasingly complex. Furthermore, the relationship between various population measures and sustenance organization enhances our understanding of differing growth and component growth patterns. In this research CIA and NMM are markedly different in their natural and absolute change indicators, whereas FF and SC counties are similar from one measure to the other in the aggregate.

## Summary and Discussion

Although the general fertility rate and total fertility rate were lowest for the natural-decrease counties, generational replacement (as measured by the replacement index) indicated that fertility was barely above replacement for all 98 nonmetro counties and below replacement level for the ND counties. Because of nearly adequate replacement fertility, net out-migration appeared in the long run to be the dominant factor in producing natural population decrease in nonmetropolitan Kansas counties. Net out-migration has been the pattern in Kansas up to the middle 1970s. It was especially great during the 1960s, when out-migrants were primarily young adults; that caused a distorted age structure, resulting in an older population and death rate that so increased that it exceeded the reproduction rate. The pattern will extend into subsequent generations because young adult out-migrants also removed their future generations. And therein lies the "momentum" of natural population decrease. Because fertility of residents is lower in natural-decrease counties than in any other county group, it results in, and is perpetuated by, age-selective out-migration. In turn, the lower fertility level helps to maintain the distorted age-structure, further evidenced by the high crude death rate in ND counties.

The natural-increase counties, especially the HNI counties, definitely fit an economic pattern. They were characterized as CIA counties with large irrigation and corporate farming practices and SC counties along an interstate highway; or they had a state university or military installation or were adjacent to an SMSA. On the other hand, ND counties were primarily FF counties, and in the southeastern part of the state they were NMM counties.

Further examining these data by measuring absolute growth or decline of counties enhanced the understanding of total population change. Although the pattern of absolute gains or losses closely followed the pattern of natural increase or decrease as Chang (1974) suggested when simply observing the total number of counties in each category, considerable variation was found when comparing natural increase-decrease with absolute growth-decline; there was a "cross-over" involving thirty-four counties (nineteen natural-increase counties that experienced absolute decline and fifteen natural-decrease counties that experienced absolute increase, both due to the effects of migration). The counties with natural population increase but absolute declines due to net out-migration quite likely will become natural-decrease counties if net out-migration continues; that is, if those leaving are young adults. However, natural population increase would increase if the out-migrants were in the older age cohorts because then the number of deaths would decrease in the denominator of the birth–death ratio.

Six counties in the southeastern block of natural-decrease counties had enough net in-migration to yield absolute growth; the two northernmost were FF counties adjacent to or near an SMSA, and the remaining four

were NMM counties (with consistent out-migration from 1940 to 1970) that formerly had been FF counties. The transition to NMM counties in the late 1960s and early 1970s and the subsequent net in-migration had not yet affected the birth–death ratios of these counties to the extent that births exceed deaths. This transition is an excellent example of the "momentum" of natural population decrease. Once a county has experienced 30 or more years of age-selective net out-migration, several years of age-selective net in-migration will not smooth out the age structure that would yield natural population increase. Sustained age-selective net in-migration, however, would likely produce natural population increase.

To summarize, first, net out-migration, and second, low fertility caused natural population decrease in the nonmetropolitan Kansas counties, as they did in Iowa as reported by Chang (1974). However, low fertility appears to be having a greater impact than in Chang's study. In 1975, it was barely above generational replacement in nonmetro Kansas. The ND counties were primarily FF counties; the natural-increase counties CIA and SC economic types. The NMM type was evenly represented by both natural-decrease and natural-increase counties. This study points up the need for studying natural population decrease-increase in conjunction with absolute growth and decline. Thirty-four of the 98 counties studied changed status when migration was included in the analysis. Counties in transition—that is, those changing sustenance opportunities (as from FF to NMM counties)—were beginning to cause a population transition, with natural population decrease being recorded along with absolute growth. With the complex process of population redistribution and nonmetropolitan growth in the U.S., including changing land use and the growth of nonmetro manufacturing and industry, simply examining natural population increase-decrease is no longer adequate in describing or explaining population change by itself. Natural population change should be examined in conjunction with social and economic characteristics (as the measures of sustenance organization in this research) and in conjunction with absolute growth-decline in order to better understand the dynamics of population change that appears to be taking on new and different forms in the past decade and in this decade. Finally, analyses as this should better serve policymakers and government officials in order to assess current and future needs of communities and people.

## Literature Cited

Beale, Calvin L. 1964. Rural depopulation in the United States: Some demographic consequences of agricultural adjustments. Demography 1:264–272.

Beale, Calvin L. 1969. Natural decrease of population: The current prospective status of an emergent American phenomenon. Demography 6:91–99.

Biggar, Jeanne C. 1979. The sunning of America: Migration to the sunbelt. Population Bulletin 34(1):1–44.

Browning, H. L., and J. P. Gibbs. 1971. Intraindustry division of labor: The States of Mexico. Demography 8(May):233–245.

Chang, H. C. 1974. Natural population decrease in Iowa counties. Demography 11:657–672.

Dorn, Harold F. 1939. The natural decrease of population in certain American communities. Journal of the American Statistical Association 34:106–109.

Flora, Jan L., and Cornelia B. Flora. 1978. Kansans on the Move. Manhattan, Kansas: Kansas State University Agricultural Experiment Station. 1–118.

Frisbie, W. Parker, and Dudley L. Poston, Jr. 1978. Sustenance Organization and Migration in Nonmetropolitan America. Iowa City: The University of Iowa Press. 1–105.

Institute for Social and Environmental Studies. 1978. Kansas Statistical Abstract, 1977. Lawrence, Kansas: University of Kansas. 1–297.

Kansas Department of Health and Environment. 1970. Annual Summary of Vital Statistics. Topeka, Kansas. 1–73

Kansas Department of Health and Environment. 1974. Annual Summary of Vital Statistics. Topeka, Kansas. 1–105.

Kansas Department of Health and Environment. 1975. Annual Summary of Vital Statistics. Topeka, Kansas. 1–109.

Kansas Department of Health and Environment. 1976. Annual Summary of Vital Statistics. Topeka, Kansas. 1–129.

McCarthy, K. F., and P. A. Morrison. 1979. The Changing Demographic and Economic Structure of Nonmetroplitan Areas in the United States. Santa Monica, California: The Rand Corporation.

Morrison, Peter A., and Judith P. Wheeler. 1976. Rural renaissance in America. Population Bulletin 31(3):1–26.

Morrison, P. A. 1978. Overview of Demographic Trends Shaping the Nation's Future. (Testimony before the Joint Economic Committee, U.S. Congress, May 31). Santa Monica, California: The Rand Corporation. 1–27.

National Cancer Institute. 1978. National Cancer Institute Age Estimates: 1970–1975. Washington, D.C.: National Cancer Institute. 1–410.

National Clearing House on Aging. 1978. The Elderly Population Estimates by County, 1976. Department of Health, Education and Welfare. 1–287.

U.S. Bureau of the Census. 1971. U.S. Census of Population: 1970. General Population Characteristics. Kansas. Final Report PC(1)-B18. Washington, D.C.: Government Printing Office. 1–287.

U.S. Bureau of the Census. 1971. U.S. Census of Population: 1970. Number of Inhabitants. Kansas. Final Report C(1)-A18. Washington, D.C.: Government Printing Office. 1–95.

U.S. Bureau of the Census. 1978. County and City Data Book, 1977. (A Statistical Abstract Supplement). Washington, D.C.: Government Printing Office. 1–956.

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# Commentary on the Kamlet-Taft Scale of Solvent Polarity for Aprotic Lewis Bases

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ABSTRACT

The generalized scale of solvent polarity ($\pi^*$) developed by Kamlet and Taft was justified originally from a modified form of reaction field theory. However, results from critical statistical tests demonstrate that such a rationalization of the $\pi^*$ scale is inadequate for both nonpolar and polar aprotic solvents. By contrast, the McRae treatment of dispersive and dipolar interactions between the solute and solvent provides a more suitable model for interpreting the seemingly general characteristics of the $\pi^*$ numbers when these are used in linear free energy correlations.

Several derived functions correlating medium effects to spectral changes and reaction kinetics for inorganic species have utilized the bulk dielectric constant and index of refraction as the variables representing the essential properties of the solvent. In an extensive critical review of literature sources Fowler, Katritzky and Rutherford (1971) noted the limitations on such single parameters when used as independent probes of solvent-solute interactions. As an alternative approach, a number of investigators have proposed various empirical parameters which are seemingly related to solvent polarity; and, among the more recent of these, the multiparameter system of Kamlet, Abboud, and Taft (1977) appears to be the most successful in interpreting a broad range of observed solvent effects upon reactions. The general linear free energy function in equation 1 relates the three Kamlet-Taft numbers for a given solvent to the observable property P and its specified reference state $P_0$.

$$P = P_0 + a\alpha + b\beta + s\pi^* \qquad (1)$$

Here, the resolved variables related to the solvent are: $\alpha$, the hydrogen bond donor acidity; $\beta$, the hydrogen bond acceptor basicity; and $\pi^*$, a measure of the intrinsic polarity-polarizability characteristics of the solvent at the molecular level. It is the theoretical support for the $\pi^*$ scale which is being re-examined in this brief communication.

## Discussion

A reasonably good empirical correlation has been observed between molecular dipole moments of aprotic solvents and their respective $\pi^*$ values (Abboud, Kamlet and Taft, 1977); and because of this, Kamlet, Abboud and Taft (1979) have applied the reaction field theory for solvent-solute interactions in justifying the $\pi^*$ polarity scale. By using the Block-Walker treatment of dielectric saturation within the solvent cavity created by the polar solute molecule, Abboud and Taft (1979) derived the reaction field function $\theta_\epsilon$ given in equation 2 where $\epsilon$ is the bulk dielectric constant of the solvent.

$$\theta_\epsilon = \frac{3\epsilon \ln \epsilon}{\epsilon \ln \epsilon - \epsilon + 1} - \frac{6}{\ln \epsilon} - 2 \tag{2}$$

As a critical test of equation 2, these investigators reported the linear correlation in equation 3 with a stated correlation coefficient of 0.964 based upon twenty-eight polar solvents.

$$\pi^* = 2.52\theta_\epsilon - 0.23 \tag{3}$$

Equations 2 and 3 have now been examined by the statistical technique of residual analysis (Kleinbaum and Kupper, 1978) in order to determine the appropriateness of the simplified reaction field model for this chemical system. The original data of Kamlet, Abboud and Taft (1979) were used to compute the standardized residual, $e_i/s$, in $\pi^*$ for the i-th solvent as a function of the independent variable ($\theta_\epsilon$); and the overall trend in the results is shown in Figure 1. Although all of the standardized residuals fall within the expected $\pm 1.96$, the distribution with respect to the zero line is clearly not a random one. The biased central points in Figure 1 correspond to solvents having intermediate dielectric constants and comprise about one-third of the data base of the model. Therefore, the seemingly acceptable correlation coefficient noted above for equation 3 appears to be fortuitous and the validity of the predicted function itself is doubtful. Similar conclusions apply to other derived functions in which the bulk dielectric constant is the sole variable related to solvent polarity. These functions have been tested with a restricted set of nonhydrogen bonding and polar aprotic solvents in order to minimize the probability of deviations arising from hydrogen bonding and other specific solvent effects.

As one considers alternative rationalizations for the $\pi^*$ scale, an appropriate starting point is to return to its phenomenological basis, i.e., the solvatochromism of the $\pi \rightarrow \pi^*$ and $p \rightarrow \pi^*$ electronic transitions for the primary indicators in nonhydrogen bonding pure solvents. Parallel arguments can be advanced between the interpretation of the red-shift shown by the $\pi \rightarrow \pi^*$ transition of Phenol Blue and its derivatives in aprotic media

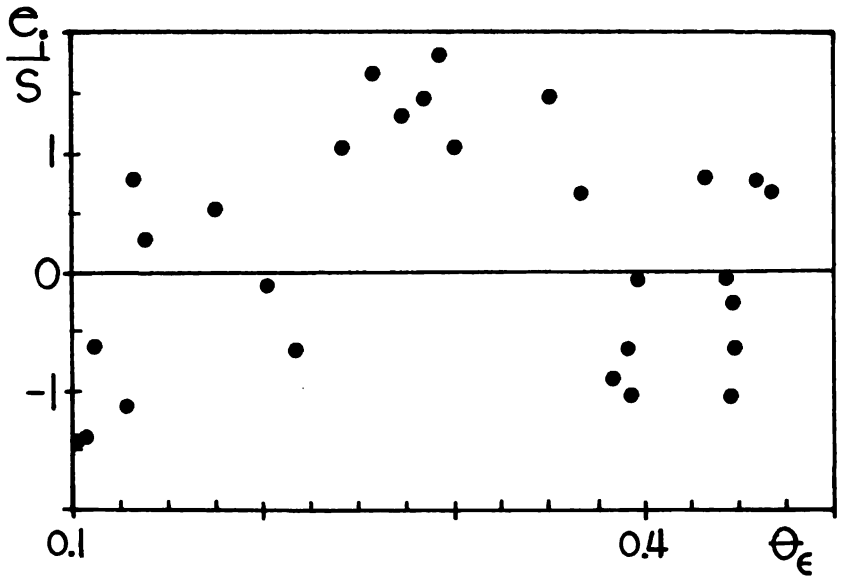


Fig. 1. Standardized residuals ($e_i/s$) for computed $\pi^*$ values as a function of the variable $\theta_\epsilon$. Based on the data of Abboud and Taft (1979).

and the solvatochromism of the simpler nitroaromatic indicators utilized by Kamlet and Taft (1977). Figueras, Scullard and Mack (1971) have demonstrated the general adequacy of the McRae function (equation 4) for resolving the influence of intrinsic solvent polarity from hydrogen bonding and other more specific solvent effects upon the bathochromic shift of the solute. In its simplest form the McRae equation relates the frequency shift or transition energy ($E_T$) to the dielectric constant ($\epsilon$) and the index of refraction (n) of the solvent (McRae, 1957).

$$E_T = A\left(\frac{n^2 - 1}{2n^2 + 1}\right) + B\left(\frac{\epsilon - 1}{\epsilon + 2} - \frac{n^2 - 1}{n^2 + 2}\right) + C \qquad (4)$$

A key assumption in the McRae perturbation theory is that the frequency shift arises from two separate sources operating in polar solvents: (a) dispersive forces between solute and solvent causing a general red shift; and (b) a group of contributions from dipolar interactions between solvent and solute to include both induced and permanent dipolar interactions governed by the Frank-Condon principle.

Thus, it must be emphasized that equation 4 is suitable where there is no significant dipole re-orientation in the excited state of the chromophore. Also, it should be noted that the first term is fully dominant only when both

the solute and solvent are nonpolar molecules. For hydrocarbons as solvents (including alkanes, cycloalkanes and aromatics), the second term in both $\epsilon$ and n equals or approaches zero; however, this is not the case when the nonpolar solvent species contains very polar C-X bonds (i.e. carbon tetrachloride).

The McRae equation has now been applied to the data in Table 1 for thirty-two solvents, including a wide range of solvent types from the nonpolar to the polar aprotic and representative very weak hydrogen bond donors (acetonitrile and nitromethane). The specific function in equation 5 was established by iterative routines and has a linear correlation coefficient of 0.944(r). Uncertainties in the constants are: ±0.1 (A); ±0.008 (B); and ±0.01 (C).

$$\pi^* \text{ (in kK)} = 14.2\left(\frac{n^2 - 1}{2n^2 + 1}\right) + 1.035\left(\frac{\epsilon - 1}{\epsilon + 2} - \frac{n^2 - 1}{n^2 + 2}\right) - 2.759 \qquad (5)$$

As will be noted from the plot in Figure 2, the scattering of the data points is random with respect to the line and is not excessive when compared to that observed in previous tests of the McRae equation with a very diverse set of solvents (Figueras, 1971 and McRae, 1957). McRae has pointed out that the approximate function in equation 4 is capable of depicting only the overall trend for the solvatochromic shift with changing solvent polarity along with identifying major graphic deviations by the stronger hydrogen bond donor solvents. Nevertheless, it is clear that equation 5 is more adequate quantitatively than the $\theta_\epsilon$ function derived from the Block-Walker treatment of solvent-solute interactions.

## Conclusion

One recent application utilizing the $\pi^*$ polarity numbers was in the quantitative expression of the polarity-polarizability influence of an uncharged Lewis base upon the ligation of zinc tetraphenylporphine (ZnTPP) in nonaqueous media (Kolling, 1979). The magnitude of the red shift for the Soret band in the spectrum of ZnTPP was explained using a multiple regression model in which the two dominant variables related to the ligand are the polarity of the donor species and its base strength as an electron pair donor.

In light of the new interpretation of the solvent effect upon the $\pi^*$ scale as given above one can return to the question concerning the suitability of the application of $\pi^*$ numbers to the correlations with the Soret shift shown by ZnTPP. Nappa and Valentine (1978) observed that among aprotic solvents the magnitude of the red shift of ZnTPP is linearly related to an index of refraction function for only a few ligands (cyclohexane, benzene, toluene, carbon disulfide); and yet according to the McRae treatment, these fall in the major group of solvents for which the dispersive contribution from the first term in equation 4 is largest.

Table 1. Summary of Solvent Parameters at 25°C.

| Solvent | $\epsilon$[a] | n[a] | $\pi^*$(kK)[b] |
|---|---|---|---|
| Acetone | 20.70 | 1.3560 | 0.683[c] |
| Acetonitrile | 37.45 | 1.3441 | 0.713 |
| Anisole | 4.33 | 1.5143 | 0.722[c] |
| Benzene | 2.28 | 1.5011 | 0.588[c] |
| Benzonitrile | 25.20 | 1.5257 | 0.904 |
| n-Butylacetate | 5.01 | 1.3830 | 0.460 |
| Butyronitrile | 20.3 | 1.3820 | 0.706 |
| Carbon tetrachloride | 21.24 | 1.3588 | 0.294[c] |
| Chlorobenzene | 5.62 | 1.5248 | 0.709[c] |
| Cumene | 2.38 | 1.4889 | 0.410 |
| Cyclohexane | 2.02 | 1.4235 | 0.000 |
| Cyclohexanone | 18.3 | 1.4509 | 0.750 |
| m-Dichlorobenzene | 5.04 | 1.5434 | 0.670 |
| 1,2-Dichloroethane | 10.36 | 1.4421 | 0.807 |
| Di-n-butyl ether | 2.77 | 1.3968 | 0.239 |
| Diethyl ether | 4.33 | 1.3495 | 0.273 |
| Dimethoxyethane | 7.20 | 1.3781 | 0.563[c] |
| N,N-Dimethylformamide | 36.71 | 1.4282 | 0.875 |
| Dimethyl sulfoxide | 46.68 | 1.4773 | 1.000 |
| Ethyl acetate | 6.02 | 1.3698 | 0.545 |
| Formamide | 108.7 | 1.4468 | 1.118 |
| n-Heptane | 1.92 | 1.3851 | −0.081 |
| n-Hexane | 1.88 | 1.3723 | −0.080[c] |
| Methyl acetate | 6.68 | 1.3610 | 0.528 |
| Nitrobenzene | 34.82 | 1.5499 | 1.029 |
| Nitromethane | 35.87 | 1.3796 | 0.848[c] |
| i-Octane | 1.94 | 1.3890 | −0.070[c] |
| Pyridine | 12.3 | 1.5095 | 0.867[c] |
| Sulfolane | 43.3 | 1.4820 | 0.977 |
| Tetrahydrofuran | 7.58 | 1.4050 | 0.576 |
| m-Xylene | 2.37 | 1.4946 | 0.464 |
| p-Xylene | 2.27 | 1.4932 | 0.426 |

[a] Dielectric constant ($\epsilon$) and index of refraction (n) data from the literature tabulation of J. A. Riddick, and W. B. Bunger. "Organic Solvents." 3rd ed.; Wiley-Interscience: New York, 1970.

[b] Composite of data published by Kamlet and Taft (1977–1979).

[c] Verified experimentally to within ±0.01 to 0.07 kK.

There is sufficient experimental support for ZnTPP functioning as a hard acid to form 1:1 complexes with a variety of neutral ligands bonded to the zinc atom lying slightly above the plane of the porphyrin ring. Thus, it is not incorrect to infer that one significant set of factors contributing to the Soret red shift by dipolar ZnTPP should originate from those very sources identified by McRae: dispersive forces and dipolar interactions. As composite measures of these two classes of polar solute-solvent interactions,

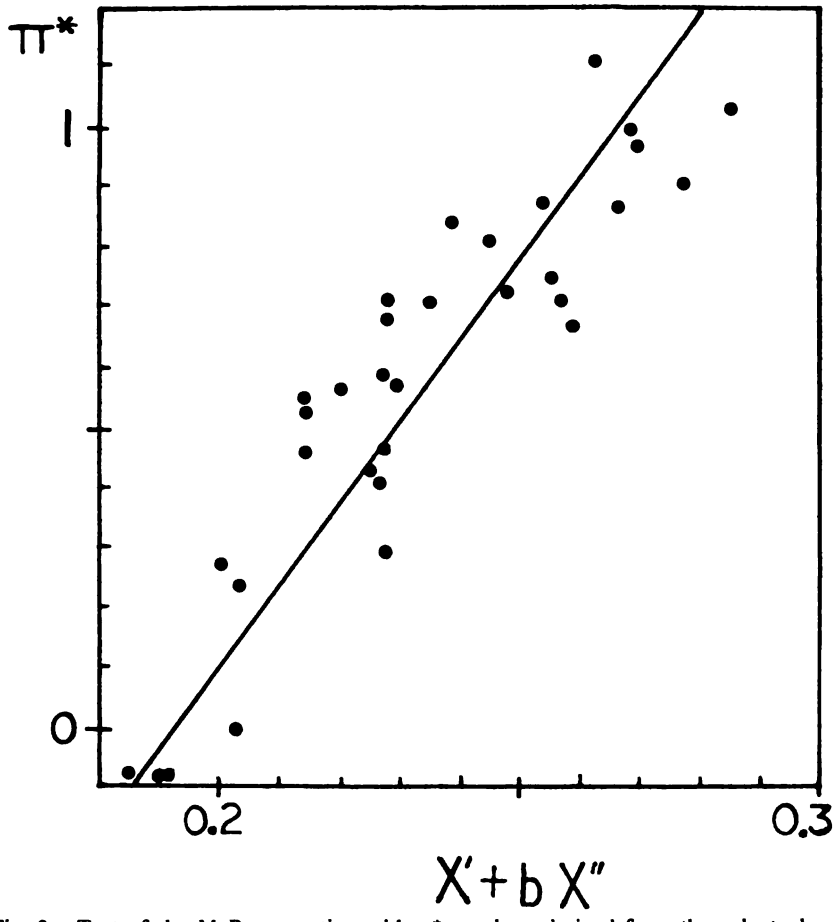


Fig. 2. Test of the McRae equation with $\pi^*$ numbers derived from the solvatochromic shifts of nitroaromatic indicators in aprotic solvents. Coordinate variable (X' + bX") is the sum of the first and second terms in the McRae eq. 4 where b = 0.0734 for the normalized function.

the $\pi^*$ numbers can be used as parameters for representing the overall influence of ligand polarity upon the solvatochromism of ZnTPP in aprotic media. Of course, the partial contribution to the Soret shift coming from the Lewis base strength of the ligand remains a resolved and additive factor for all polar aprotic donors toward ZnTPP and requires a second parametric variable in the linear regression model (Kolling, 1979).

## Literature Cited

Abboud, J., M. Kamlet, and R. Taft. 1977. Regarding a Generalized Scale of Solvent Polarities. J. Am. Chem. Soc. 99:8325.

Abboud, J., and R. Taft. 1979. An Interpretation of a General Scale of Solvent Polarities. J. Phys. Chem. 83:412.

Figueras, J. 1971. Hydrogen Bonding, Solvent Polarity and the Visible Spectrum of Phenol Blue. J. Am. Chem. Soc. 93:3255.

Figueras, J., P. Scullard, and A. Mack. 1971. Synthesis and Spectral Properties of Some Derivatives of Phenol Blue. J. Org. Chem. 36:3497.

Fowler, F., A. Katritzky, and R. Rutherford. 1971. Correlation of Solvent Effects on Physical and Chemical Properties. J. Chem. Soc. (B):460.

Kamlet, M., J. Abboud, and R. Taft. 1977. The Solvatochromic Comparison Method. J. Am. Chem. Soc. 99:6027.

Kamlet, M., T. Hall, J. Boykin, and R. Taft. 1979. Linear Solvation Energy Relationships. J. Org. Chem. 44:2599.

Kamlet, M., M. Jones, R. Taft, and J. Abboud. 1979. Linear Solvation Energy Relationships. Part 2. J. Chem. Soc. Perkin Trans. II:342.

Kleinbaum, D., and L. Kupper. 1978. Applied Regression Analysis and Other Multivariable Methods. Wadsworth, Belmont, Calif. pp.235–241.

Kolling, O. W. 1979. Soret Red Shift for Zinc Tetraphenylporphine. Inorg. Chem. 18:1175.

McRae, E. G. 1957. Theory of Solvent Effects on Molecular Electronic Spectra. J. Phys. Chem. 61:562.

Nappa, M., and J. Valentine. 1978. Influence of Axial Ligands on Metalloporphin Visible Absorption Spectra. J. Am. Chem. Soc. 100:5075.

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# Miscellaneous Notes on the Reproductive Biology of Reptiles. 4. Eight Species of the Family Boidae, Genera *Acrantophis, Aspidites, Candoia, Liasis* and *Python*

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ABSTRACT

Sequences of courtship and copulation, egg-laying and parturition, with data on the neonates are presented for eight boid taxa: *Acrantophis dumerili, A. madagascariensis, Aspidites melanocephalus, Candoia bibroni, Liasis boa, L. childreni, L. mackloti* and *Python boeleni*. The functional use of spurs during courtship is recorded in *Acrantophis dumerili, A. madagascariensis, Aspidites melanocephalus, Candoia bibroni* and *Python boeleni*. Combat preceding courtship between males occurs in *A. melanocephalus* and *A. dumerili*.

In an earlier contribution, Murphy et al. (1978) described sequences of courtship and copulation, egg-laying and parturition with data on the neonates for eleven boid taxa. These authors provided some descriptions for spur usage in boid snakes. Combat between male boid snakes has been reported in *Sanzinia madagascariensis* (Carpenter et al., 1978), *Aspidites melanocephalus* and *Python molurus* (Barker et al., 1979). In captive *P. molurus*, a linear social hierarchy was formulated which was reinforced by male combat, and breeding sequences were accomplished according to the hierarchial position of a male. This paper provides additional reproductive data and combat sequences in some snakes mentioned by Murphy et al. (1978), and incorporates information on other taxa of captive boids.

## MATERIALS AND METHODS

All observations were carried out at the Dallas Zoo with captive snakes. Taxonomic allocations follow McDowell (1975, 1979) and Guibé (1949, 1958).

Thermal environments were established for the specimens observed on the basis of studies by Cogger and Holmes (1960), Hutchison et al. (1966), Vinegar et al. (1970), Webb and Heatwole (1971), Johnson et al. (1975),

Johnson (1972, 1973, 1977) and Van Mierop and Barnard (1976, 1978). Ambient temperature varied between 27–34°C. Thermal gradients were made available to all snakes by using infra-red bulbs to create "hot spots" which reached 34.0 ± 2.0°C in temperature. Impregnated females regularly used these basking sites. Skylights provided a natural photoperiod, and fluorescent lights (cool white, 25–40 watt/110 volt) were used to provide additional illumination. Artificial light durations were altered to correspond to a natural photoperiod.

Eggs were measured with a vernier caliper to the nearest 1.0 mm and weighed with a triple-beam balance to the nearest 0.1 gram. Neonates were measured to the nearest 1.0 mm (Quinn and Jones, 1974). Hiding boxes with damp sphagnum moss were provided for gravid females, and eggs were hatched using the method of Tryon (1975). The incubation temperature was 32 ± 1.0°C for the eggs. Relative humidity averaged 50 percent. All snakes were fed freshly killed laboratory rodents and chicks, and drinking water was available *ad libitum*. Courtship terminology follows Gillingham (1974, 1976) and Gillingham et al. (1977).

## Species Accounts

*Acrantophis dumerili.* Two male and two female snakes of this species were housed in a glass-fronted fiberglass unit measuring 71 × 81 × 117 cm high, with decorative branches and a gravel substrate. Both males were from unknown localities and were available on temporary breeding loan. The males measured 158 and 155 cm in total length. The females were collected at Manja, Malagasy, on 9 March 1970 and 5 August 1973, and measured 151 and 142 cm, respectively. Sequences of male combat and courtship were recorded on 9 and 23 July 1979. Additional courtship without male combat was observed on 16 September.

The following account is based on behavior which occurred on 9 July and the males are designated according to final status:

1130 hours: Subdominant male (S) and both females were in the enclosure.

1131: Dominant male (D) was introduced into the unit. In less than one minute, D pursued S. D bit S on the trunk 30 cm anterior to his vent, then constricted the subdominant's trunk by encirclement with two coils. D vibrated his spurs at a frequency of 2 strokes/second. Spurs often operated independently and at different speeds. When operating at the same speed, spurs usually moved alternately. Speed of vibration seemed to be determined by resistance of the object against which the snake's tail was resting (i.e., the side of the unit stimulated vigorous spur activity). Spurs were extended *ca.* 6 mm and moved in an anterior direction. When D was moving spur usage continued, but the spurs occasionally stopped when the snake was

quiescent. S did not vibrate its spurs. During biting episodes, D first tested the dorsum of S with his tongue, then slowly opened his mouth in a very wide gape and attempted to bite. After immobilization by biting, D attempted to constrict S if the latter snake was unable to escape. Females were never bitten. S withdrew by crawling into decorative branches in the unit.

1215: D encountered S as the latter snake was descending from the branches. D bit S in the region of the vent, then encircled the subdominant snake with two coils.

1218: D released bite hold: S escaped.

1231: D bit S, then pressed the latter snake's head against the substrate with a midbody coil. S pulled away.

1240: D pressed the trunk of S against the substrate for 20 minutes. S unsuccessfully tried to escape.

1300: S was removed from cage for fear of injury.

1340: D prowled the unit with spurs continuing to vibrate.

1430: D began to court the larger female (tactile-chase).

1500: D continued to court the female by using spurs to position the female's vent. He used the spurs to probe the interstitial skin which often stimulated the female to crawl forward. This behavioral sequence closely duplicated the description of courtship in *Candoia bibroni* (Murphy et al., 1978), but the vibration of the male's spurs averaged one stroke per second.

1600: D tried to align by crawling anteriorly along the female's dorsum. A light rhythmic vibration of the spurs was applied to the trunk and tail of the female, especially along the lateral surfaces.

1615: Female began to move more rapidly with the male pursuing. Spur speed increased to 2 per second. Tongue flick frequency averaged one per 2 seconds as D moved anteriorly along the female's dorsum.

1616: Other female was removed.

1630: D tried to align by crawling anteriorly along the female's dorsum; she began to crawl rapidly. Both snakes used rectilinear locomotion, but occasionally an undulating movement was used to build coils for rapid progression.

1635: D aligned on the female's dorsum by using short radius coils. The female remained quiescent. The male rotated his tail 90° and pressed his vent region in apposition to the female's cloaca by aligning against the lateral margin. The male jerked convulsively four times in five minutes (tactile-alignment).

1640: The male jerked convulsively twice. The left hemipenis was inserted (intromission and coitus). He continued to press his vent region against the female's vent and continued occasional spur vibration. The female remained immobile. The heads were separated *ca.* 25

cm. The posterior one-third of the bodies were aligned but the anterior portions were separated.

1706: D retracted his hemipenis from the female's cloaca; his vent remained slightly agape for 2 minutes.

1708: The male began to crawl and continued his spur action.

1800: Spur action ceased. Observations discontinued.

Male combat was also observed on 23 July during a 50 minute encounter; behavior was similar to that described above. Copulation between the dominant male and the other female occurred on 16 September 1979.

Comparisons of literature reports (Carpenter et al., 1978; Barker et al., 1979) suggest that male combat in *A. dumerili* more closely duplicates behavior observed in *Python molurus* than in *Sanzinia*. Physical encounters may be less ritualized than either *Sanzinia* or *P. molurus*, since biting and constriction are often apparent in *A. dumerili*. Behavioral components listed for *P. molurus*, but not seen in *Acrantophis*, include evacuation of cloacal contents, hissing, tail raising and excretion of musk. Adpression of the combatant's trunk on the substrate occurred regularly in *Acrantophis*, and this behavior seemed to be an important element for immobilization of subdominant specimens.

*Acrantophis madagascariensis*. A male specimen measuring 185 cm in total length was available to us on temporary breeding loan; the snake was from an unknown locality. Two females were acquired by us on 20 July 1969; one from Soalala, Malagasy and the other from an unknown locality. They measured 168 and 170 cm total length, respectively. The snakes were maintained in an exhibit enclosure which was decorated with branches and plastic foliage, and which measured 100 × 80 × 113 cm high. The substrate was small gravel. Precoital behavior was observed on 9 July 1979. When discovered at 0850 hours, the male was aligned upon the dorsum of the larger female. Intermittent use of the male's spurs occurred to align with the female's vent, as in *Candoia bibroni* (Murphy et al., 1978). The male attempted to place the cloacae in apposition by crawling either backwards or forwards with rectilinear movement as the female slowly moved; he also placed loosely draped coils over the female's coils when she remained quiescent. The male on occasion would probe the female's interstitial skin violently with his spurs, causing her to move rapidly. Alignment and position of the vents approximated that of *A. dumerili*. At 1015 hours the male placed his head on the female's dorsum *ca.* 45 cm posterior to her head; then he violently convulsed and quickly everted his left hemipenis against the right lateral margin of the female's vent. The extruded organ was *ca.* 38 mm in length; the basal portion was *ca.* 7 mm in diameter. The female did not move or tongue flick during the entire precopulatory sequence. The male everted his hemipenis twice during unsuccessful attempts at intromission. No rhythmic vibration of spurs or tongue-flicking occurred when the male

was immobile. For 30 minutes both snakes remained quiescent. At 1601 hours the male convulsed and extruded the right hemipenis without penetration. Intromission was unsuccessful and courtship ceased at 1200 hours.

*Aspidites melanocephalus*. Two male snakes of this species, acquired 22 September 1968 and 13 April 1970, measured 188 and 200 cm total length, respectively. A female was acquired on 12 March 1973 and measured 209 cm in total length. All were from unknown localities. They were maintained in a glass-fronted exhibit unit measuring 78 × 81 × 117 cm high, and decorated with rocks, stumps and plastic foliage. The substrate was small gravel. The males were kept together from September through January. When the female was introduced in January, the males were rotated at roughly one week intervals. The unit was sprayed with water four or five times per week from July through December, and all snakes raised heads in a vertical plane during these sprayings. Vertical head positioning suggests thermoregulatory behavior (Johnson, 1973).

Combat between males has been described earlier (Barker et al., 1979). Spur movement varied with as many as 8–10/5 seconds flexion-extension sequences to as slow as one stroke/2 seconds. Tails were tightly intertwined, but heads and anterior trunks appeared to have no particular orientation. No constriction of objects in the enclosure or pulling with heads or anterior trunks was observed as in *Sanzinia* (Carpenter et al., 1978). Biting never occurred and we were unable to determine how dominance was achieved.

Copulation in this species was observed on 5 March 1979. During the gestation period, the female was often lying with her dorsum contacting the substrate, and occasionally all but her head would be in contact. All three snakes regularly excavated the substrate extensively, usually near an object in the enclosure. Excavation was accomplished by forming the head and anterior trunk into a "J" configuration, moving sideways, then pulling the gravel entrapped by the head-neck angle toward the posterior trunk. The female dug continuously from the time of copulation until oviposition.

Six adherent off-white eggs were laid on 25 March 1979 in damp sphagnum moss which was provided for oviposition. Measurements and weights of the eggs are as follows: length 100–112 mm, $\bar{x}$ = 104; diameter 47–51 mm, $\bar{x}$ = 49; weight of adherent clutch 820 g, $\bar{x}$ = 136. All eggs hatched on 16 June 1979 and the measurements and weights of the neonates are as follows: total length 58.0–62.0 cm, $\bar{x}$ = 60.0; tail length 6.4–7.2 cm, $\bar{x}$ = 6.7; weight 76.5–83.5 g, $\bar{x}$ = 81.3. The young resembled the parents in coloration (Fig. 1). They were dark brown to black above, lighter on the sides (tan) with numerous reddish-brown or blackish crossbands which exhibited an orange hue toward the venter and were narrower than the interspaces. Head, neck and throat jet black. Belly cream to yellow, occasionally with darker blotches.

Our data differ in some respects from Boos (1979) in that our clutch size

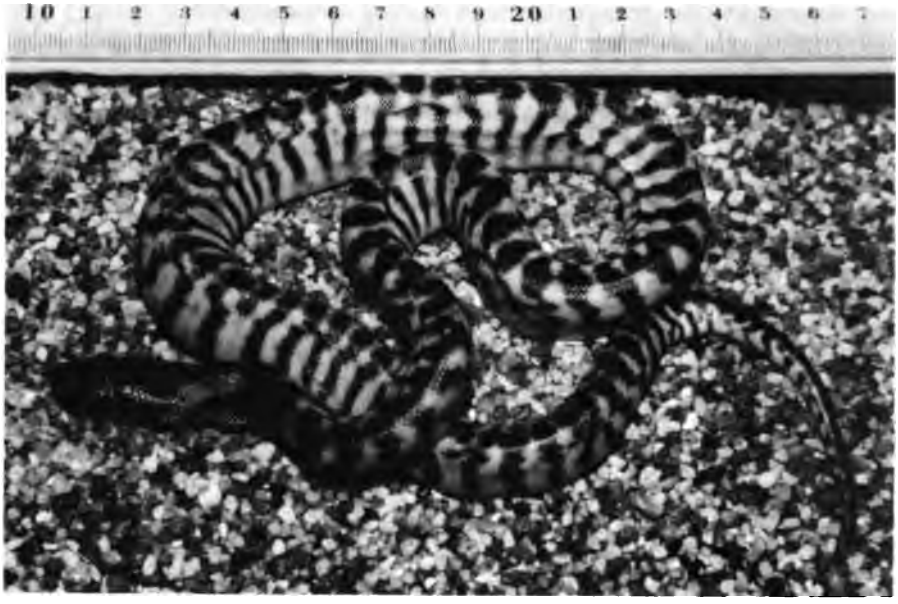

Fig. 1. Hatchling *Aspidites melanocephalus*.

was smaller, eggs and hatchlings were larger, and the female did not twitch after oviposition. The differences in dates of oviposition and hatching could be explained by seasonal reversal.

The young were offered freshly killed laboratory mice (7.5 g), but these were refused. The snakes were assistance-fed by gently opening the mouths and placing heads of mice therein. The snakes swallowed the mice without mishap and began feeding voluntarily four to five weeks later.

*Candoia bibroni*. Courtship behavior for this species has been described earlier (Murphy et al., 1978). On 22 August 1978 a female gave birth to three young and passed three infertile egg masses. One of the young exhibited fused portions of the vertebral column (KU 182375). Measurements and weights of the two survivors are as follows: total length 275–300 mm, $\bar{x}$ = 287; tail length 43–45 mm, $\bar{x}$ = 44; weight 10.0–10.5 g, $\bar{x}$ = 10.2. The smaller neonate had a slightly deformed jaw and later died (KU 182376).

Coloration and pattern of the adults and young are as follows (McDowell, 1979:22): smaller male—D. Blotched pattern with median throat stripe; larger male—C. Blotched pattern with throat stripe; female—E2. Blotched pattern without stripes; neonates—C and D. Unlike the adults, the ground color of the neonates was reddish.

On 15 September 1979 the smaller male was copulating with the female at 0815 hours. The male's tail encircled the female's trunk with three coils.

Disengagement occurred at 1130 hours. Both males remained active for three hours, and the smaller male intermittently contacted the trunk of the larger male with his spurs moving in a scratching action. No entwining of the tails or trunks was apparent.

*Liasis boa.* Four snakes of this species were available for study: male A, acquired 23 February 1973 and measuring 126 cm total length (from New Ireland Island); male B, acquired 7 September 1971 and measuring 145 cm (from an unknown locality); female A, acquired during June 1973 and measuring 1220 mm (from Rabaul, New Britain Island) (KU 180255); female B, acquired on a temporary breeding loan and measuring 145 cm (from an unknown locality). All snakes exhibited a banded color phase.

Both males were introduced during early January 1978 into an exhibit unit measuring 100 × 80 × 113 cm high. Plastic plants and branches were arranged throughout the enclosure. The substrate was small gravel and a pool with running water was available. Male A often pursued the larger male, but no physical contact was observed. Intermittent courtship occurred on 23 February 1978 and 31 January, 27 February and 3 March 1979 but complete courtship sequences were not seen. In all instances, male A crawled after the slowly crawling female B. Rhythmic vibrations of the spurs averaged two strokes per second. Oviposition occurred on 31 May which consisted of nine fertile and four infertile egg masses. Measurements and weights of the fertile eggs are as follows: length 34–50 mm, $\bar{x}$ = 45; diameter 26–31 mm, $\bar{x}$ = 29; weight of ivory, slightly granular adherent clutch 187.0 g, $\bar{x}$ = 20.7. On 5–6 August 1978 all fertile eggs hatched and the neonates were weighed and measured as follows: total length 260–334 mm, $\bar{x}$ = 312; tail length 35–43 mm, $\bar{x}$ = 40; weight 7.4–13.4 g, $\bar{x}$ = 11.2.

Total number of orange bands (including incomplete bands) varied between 31–36, $\bar{x}$ = 33; tail bands 5–7, $\bar{x}$ = 6. One of the young expired (KU 182377).

Coloration of the young has been described by Rooij (1917) and Schmidt and Inger (1957). The orange bands were vivid and according to the color standard of Maerz and Paul (1930), were Sungod (plate 2, H 12).

On 17 April 1979, female B laid 16 adherent eggs which were measured and weighed as follows: length 42–50 mm, $\bar{x}$ = 45, diameter 29–33 mm, $\bar{x}$ = 32; weight of adherent clutch 357 g, $\bar{x}$ = 22. Hatching occurred on 3–5 July and all young emerged. Measurements and weights are as follows: total length 304–333 mm, $\bar{x}$ = 325; tail length 35–42 mm, $\bar{x}$ = 38; weight 11.2–14.6 g, $\bar{x}$ = 13.0. Total number of orange bands (including incomplete bands) varied between 29–37, $\bar{x}$ = 33; tail bands 5–7, $\bar{x}$ = 6. Grand means across both clutches are as follows: eggs—length 45 mm, diameter 32 mm, weight 21.7 g; neonates—total length 320 mm, tail length 39 mm, weight 12.3 g.

Ontogenetic color change was recorded, and within three months the vivid

orange color was greatly subdued. In six months, no traces of orange were noticeable; the color was olive brown and yearlings were virtually indistinguishable from adults.

Young from the first brood were difficult to feed and many would only accept small lizards (*Leiolopisma*). Gradually, the snakes began feeding upon newborn mice. All snakes from the second brood accepted newborn mice voluntarily.

*Liasis childreni.* Two males of this species were acquired during January 1968 and on 23 November 1976, and two females were acquired on 20 December 1972 and 23 November 1976. The larger male measured 115 cm total length, the smaller male measured 89 cm, and the females measured 121 and 96 cm, respectively. All were from unknown localities. The snakes were maintained in an exhibit unit measuring 77 × 50 × 37 cm high. Plastic plants, branches and rocks were arranged throughout the enclosure and the substrate was small pebbles.

Courtship was recorded on 20 November 1977, 19 February 1978 and 23 January 1979. The smaller male bred the larger female on 23 February 1978. In all instances, males aligned the cloacae and encircled the tails of females with their tails; when intromission was accomplished, occasional pulsations occurred at the rate of *ca.* one per minute. Complete courtship sequences were not seen.

A clutch of twelve adherent eggs was laid on 5 April 1978 by the larger female, but the eggs were not weighed and measured. All eggs hatched between 31 May and 2 June and the neonates were measured and weighed as follows: snouth-vent length 218–247 mm, $\bar{x}$ = 231; tail length 24–30 mm, $\bar{x}$ = 27; weight, 7.7–10.5 g, $\bar{x}$ = 8.7.

Coloration and pattern of the young resembled the adults in that the ground color was the same as the parents, but the pattern was lighter. One of the young later died (KU 182378).

Reproduction has been treated by Ross (1973), Dunn (1979) and observed by S. Chiras (pers. comm.).

*Liasis mackloti.* A male measuring 1.85 m total length and a female measuring 1.9 m were acquired on 29 November 1969. Both were from unknown localities. Coloration of the snakes conforms most closely to McDowell's (1975:36) description of individuals of this taxon from New Guinea and Australia.

These snakes were discovered copulating on 9 March 1979 at 0830 hours. No spur activity was evident. The female was often lying with her dorsum contacting the substrate prior to oviposition.

Deposition of twelve off-white adherent eggs occurred on 9 April and measurements and weights are as follows: length 50–70 mm, $\bar{x}$ = 63; diameter 38–42 mm, $\bar{x}$ = 40; weight of clutch 685 g, $\bar{x}$ = 57. All eggs hatched on 22 June and the measurements and weights of nine full term young are as follows: total length 370–490 mm, $\bar{x}$ = 441; tail length 60–73 mm,

$\bar{x}$ = 74; weight 23.0–36.7 g, $\bar{x}$ = 30.6. Three young were fully formed but dead at birth (KU 182379–381). The young resembled the adults in having dark brown coloration vertebrally, coral blush venter (Maerz and Paul, 1930, plate 1, F. 10), unmarked white chin extending to first ventral; tail dark, slightly lighter than vertebral color.

Reproduction has been treated by Ross (1977, 1978) and Boos (1979).

*Python boeleni.* Courtship behavior in this taxon has been described earlier (Murphy et al., 1978). Two additional specimens from the Wissel Lakes region in West Irian were available for study. The original male measured 2.70 m total length, the newer male measured 2.75 m, the original female measure 2.9 m and the newer female measured 2.80 m. The snakes were maintained in a glass-fronted enclosure measuring 3.7 × 1.6 × 3.5 m high. The walls were covered with ornamental rock and vines were arranged throughout the unit. A large tree stump was placed on the floor of the enclosure. The snakes were arboreal and their tails were strongly prehensile.

Courtship and copulatory sequences were recorded on 21 January, 12 February, 25, 26 May, 17 July, and 14 September 1979 in addition to those mentioned by Murphy et al. (1978). The following account is a compilation of behaviors involving the newer male and older female. Female ecdysis often stimulated male courtship episodes. If the female was in a resting coil, the male nudged her body with his snout to provoke her to move. If this behavior was unsuccessful, the male crawled away from her until his vent region was aligned above her coils; then he turned and crawled back toward the female until both his head and tail were in contact with her. When the female's trunk was touched by the male's tail, he began vigorous rhythmic vibrations with the spurs. As the female began to move, the male aligned his head with hers, then aligned the bodies as the female continued to crawl.

On three occasions, the snakes were visually separated by the stump. The female was in a resting coil and the male crawled around the stump until visual contact was made *ca.* 50 cm from her head. If the female was in a position to see the male, he immediately withdrew his head behind the stump. At intervals of 15 seconds–2 minutes, he extended his head and neck until visual contact was made. This head extension-withdrawal behavior was seen as many as twenty times. If the female's head was either pointing away from the male or if she turned her head away from him, he crawled rapidly toward her, aligned his head and tail on her coils, and began the rhythmic spurring described earlier. Spur cadence varied between 1–2 strokes/second. When the smaller female was approached by the male, the former invariably withdrew. The coital duration in one instance was 50 minutes. The male's tail did not encircle the female's tail. No spur movement or pulsations were evident. The pair remained motionless during coitus and the snakes were copulating in the branches in one instance. Combat between males was not seen as the smaller male always fled.

Between 0800–1230 hours, the smaller female laid nine eggs and passed

five infertile egg masses on 20 May 1979. The eggs were measured and weighed: length 74–96 mm, $\bar{x}$ = 83; diameter 42–54 mm, $\bar{x}$ = 45; weight 73–126 g, $\bar{x}$ = 107. On 26 May the eggs began to deteriorate and only one egg remained by 13 June. Twenty days later the remaining egg collapsed; dissection revealed a dead embryo lacking pigment but scales were formed.

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Many of the snakes upon their death have been or will be placed in the vertebrate collections of the University of Texas at Arlington (UTA) and the University of Kansas at Lawrence (KU).

## Literature Cited

Barker, D. G., J. B. Murphy, and K. W. Smith. 1979. Social behavior in a captive group of Indian pythons, *Python molurus* (Serpentes, Boidae) with formation of a linear social hierarchy. Copeia 1979:466–471.

Boos, H. E. A. 1979. Some breeding records of Australian pythons. Int. Zoo Yearb. 19:87–89.

Carpenter, C. C., J. B. Murphy, and L. A. Mitchell. 1978. Combat bouts with spur use in the Madagascan boa (*Sanzinia madagascariensis*). Herpetologica 34:207–212.

Cogger, H. G., and A. Holmes. 1960. Thermoregulatory behavior in a specimen of *Morelia spilotes variegata* Gray (Serpentes, Boidae). Proc. Linn. Soc. (New South Wales) 85:328–333.

Dunn, R. W. 1979. Breeding Children's pythons *Liasis childreni* at Melbourne Zoo. Int. Zoo Yearb. 19:89–90.

Gillingham, J. C. 1974. Reproductive behavior of the western fox snake *Elaphe v. vulpina* (Baird and Girard). Herpetologica 30:309–313.

Gillingham, J. C. 1976. Reproductive behavior of the ratsnakes of eastern North America, genus *Elaphe*. Doctoral thesis, Univ. Oklahoma, Norman. 62 pp.

Gillingham, J. C., C. C. Carpenter, B. J. Brecke, and J. B. Murphy. 1977. Courtship and copulatory behavior of the Mexican milksnake, *Lampropeltis triangulum sinaloae* (Colubridae). Southwest. Nat. 22:187–194.

Guibé, J. 1949. Révision des Boidés de Madagascar. Mém. Inst. Sci. Madag. A. 3:95–105.

Guibé, J. 1958. Les Serpentes de Madagascar. Mém. Inst. Sci. Madag. A. 12:189–260.

Hutchison, V. H., H. G. Dowling, and A. Vinegar. 1966. Thermoregulation in a brooding female Indian python, *Python molurus bivittatus*. Science 151:694–696.

Johnson, C. R. 1972. Thermoregulation in pythons—I. Effect of shelter, substrate type and posture on body temperature of the Australian carpet python, *Morelia spilotes variegata*. Comp. Biochem. Physiol. 43A:271–278.

Johnson, C. R. 1973. Theremoregulation in pythons—II. Head-body temperature differences and thermal preferenda in Australian pythons. Comp. Biochem. Physiol. 45A:1065–1087.

Johnson, C. R. 1977. Thermoregulation in pythons—IV. Theremoregulation in the Papuan-New Guinean pythons within the genera *Python, Liasis* and *Chondropython*. Zool. J. Linn. Soc. 60:189–195.

Johnson, C. R., G. J. W. Webb, and C. Johnson. 1975. Thermoregulation in pythons—III. Thermal ecology and behavior of the black-headed rock python, *Aspidites melanocephalus*. Herpetologica 31:326–332.

Maerz, A., and M. R. Paul. 1930. A dictionary of color. McGraw-Hill, Inc. New York. vii + 207 pp.

McDowell, S. B. 1975. A catalogue of snakes of New Guinea and the Solomons, with special reference to those in the Bernice P. Bishop Museum. Part II. Anilioidea and Pythoninae. J. Herp. 9:1–79.

McDowell, S. B. 1979. A catalogue of snakes of New Guinea and the Solomons, with special reference to those in the Bernice P. Bishop Museum. Part III. Boinae and Acrochordoidea. (Reptilia, Serpentes). J. Herp. 13:1–92.

Murphy, J. B., D. G. Barker, and B. W. Tryon. 1978. Miscellaneous notes on the reproductive biology of reptiles. 2. Eleven species of the family Boidae, genera *Candoia, Corallus, Epicrates* and *Python*. J. Herp. 12:385–390.

Quinn, H., and J. P. Jones. 1974. Squeeze box technique for measuring snakes. Herp. Rev. 5(2):35.

Rooij, N. de. 1917. The reptiles of the Indo-Australian Archipelago. II. Ophidia. Leiden: E. J. Brill. 331 pp.

Ross, R. 1973. Successful mating and hatching of Children's python, *Liasis childreni*. HISS. News-Journal 1(6):181–182.

Ross, R. 1978. The python breeding manual. Published privately by Institute for Herpetological Research, Stanford, California. pp. 1–51.

Ross, R., and R. Larman. 1977. Captive breeding in two species of python *Liasis albertisii* and *L. mackloti*. Int. Zoo Yearb. 17:133–136.

Schmidt, L. P., and R. F. Inger. 1957. Living reptiles of the world. Garden City, New York: Doubleday. 287 pp.

Tryon, B. 1975. How to incubate reptile eggs; a proven technique. Bull. N. Y. Herp. Soc. 11:33–37.

Van Mierop, L. H. S., and S. M. Barnard. 1976. Thermoregulation in a brooding female *Python molurus bivittatus* (Serpentes, Boidae). Copeia 1976:398–401.

Van Mierop, L. H. S., and S. M. Barnard. 1978. Further observations on thermoregulation in the brooding female *Python molurus bivittatus* (Serpentes, Boidae). Copeia 1978:615–621.

Vinegar, A., V. H. Hutchison, and H. G. Dowling. 1970. Metabolism, energetics, and thermoregulation during brooding of snakes of the genus *Python* (Reptilia, Boidae). Zoologica 55:19–48.

Webb, G., and H. Heatwole. 1971. Patterns of heat distribution within the bodies of some Australian pythons. Copeia 1971:209–220.

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# Additional Data on the Metabolism of Two Diptera Larvae, *Chaoborus punctipennis* and *Chironomus plumosus*

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ABSTRACT

Three separate investigations using standard Warburg techniques were employed to gather and compare respiratory metabolism data on two aquatic dipteran larvae *Chaoborus punctipennis* (Say) and *Chironomus plumosus* (Linnaeus). Under aerobic conditions, *C. punctipennis* larvae consumed about three times as much oxygen and expelled less carbon dioxide than *C. plumosus* larvae. The R.Q. of *C. punctipennis* larvae was 1.00 while that of *C. plumosus* larvae was 1.29. Under anaerobic conditions, the acids excreted by *C. punctipennis* larvae were about 3.3 times the amount excreted by *C. plumosus* larvae. Under natural conditions, both species probably produce fatty acids but they are formed and excreted in different ways. *C. plumosus* larvae lack the means to entirely relieve their oxygen debt, thus they occupy the muds of shallow oxygenated waters most of the time. *C. punctipennis* larvae can rid themselves of a temporary oxygen debt by migrating to surface waters from oxygen depleted, bottom muds. The diurnal vertical migration behavior of *C. punctipennis* larvae may be a direct response to oxygen availability.

Significant differences in the distribution and behavior between two selected species of aquatic dipteran larvae in bodies of standing waters have been observed and recorded many times (Fox et al., 1955; Wood, 1956; Stahl, 1959, 1966; LaRow, 1968; Ransom et al., 1970). *Chironomus plumosus* (Linnaeus) larvae are most often found in the muds of shallow waters and *Chaoborus punctipennis* (Say) larvae generally inhabit the bottom muds of deeper waters. Third and fourth instar larvae of *C. punctipennis* perform diurnal vertical migrations while the larvae of *C. plumosus* do not perform such migrations. There has been increasing interest in research during the last several years which might explain the differences in distribution and behavior of the larvae of these two species.

Emergence from the bottom mud and subsequent upward migration of *C. punctipennis* larvae occurs closely with the setting of the sun. LaRow (1968)

demonstrated that the phase of the diurnal vertical migration of *C. punctipennis* was due to an internally regulated clock mechanism affected by temperature and delayed or advanced by conditioning the larvae under different light regimes.

Stahl (1966) stated that *Chaoborus* larvae probably feed in the upper waters, but that has never been proved. According to Deonier (1943) and Main (1953), *Chaoborus* larvae do not need to migrate in order to find many of their preferred food items. Ransom (1969) collected no *Chaoborus* larvae from the upper waters at any time in February, and the number of larvae in the bottom muds remained essentially the same at each collection time during a 24 hour period. It seems unlikely that *C. punctipennis* larvae migrate upward for the purpose of feeding only.

Prosser (1955), Bullock (1955), and Fromm (1965) in reviews on the distribution of species pointed out that physiological limitations can describe the ecological range of an animal. Thus, it seemed possible that differences in distribution and behavior between *C. punctipennis* larvae and *C. plumosus* larvae could be accounted for by differences in ability of the two larvae to carry on anaerobic respiration.

The primary objective of this study was to repeat as nearly as possible the Ransom et al. (1970) preliminary investigation on gas exchange and acid production by *C. plumosus* and *C. punctipennis* larvae and to note whether or not similar results could be obtained.

## Materials and Methods

Larvae of *Chaoborus punctipennis* were collected from Gladfelter Pond on the Emporia State University Ross Natural History Reservation. These larvae were transported to the laboratory in plastic buckets containing pond water and some bottom mud. Larvae of *Chironomus plumosus* were collected with a dip net from a roadside ditch containing standing water and were transported to the laboratory in ditch water. Final instar larvae of both species were used in data collecting.

Standard Warburg manometric techniques were utilized to measure oxygen consumption and carbon dioxide production by the larvae on three consecutive days. The direct method was employed and the total uptake procedure was used to make calculations as described by Umbreit et al. (1957). After an equilibration period of ten minutes measurements were taken at ten minute intervals over a two-hour period and all measurements were made at 25 C. Measurements were made on both species in atmospheric air and in an anoxic atmosphere of nitrogen. Filtered pond water was used in the flasks containing 50 *C. punctipennis* larvae and filtered ditch water was used in the flasks containing 25 *C. plumosus* larvae each. Acid production was determined by use of a gas chromatograph.

Table 1. Gas Exchange and Acid Production in the Midge Larvae *Chaoborus punctipennis* and *Chironomus plumosus*.*

| Determination** | *C. punctipennis* | *C. plumosus* |
|---|---|---|
| Dry wt (mg/individual) | 0.15 | 1.10 |
| $Q_{O_2}$ ($\mu$L $O_2$/mg dry wt/hr) | 5.59 | 1.49 |
| $Q_{CO_2}$ ($\mu$L $CO_2$/mg dry wt/hr) | 5.59 | 1.89 |
| R.Q. | 1.00 | 1.29 |
| $\mu$ moles acid excreted/mg dry wt/hr | 200 | 60 |

* Numbers represent mean of three separate investigations.
** All data were converted to mean per individual.

## Results and Discussion

The $Q_{O_2}$ ($\mu$L $O_2$/ mg dry wt/hr) and $Q_{CO_2}$ ($\mu$L $CO_2$/mg dry wt/hr) of *Chaoborus punctipennis* larvae was about 3.7 times greater than that of *Chironomus plumosus* larvae (Table 1). The dry weight per individual of fourth instar larvae of *C. plumosus* was about seven times more than the dry weight per individual of fourth instar larvae of *C. punctipennis*. Usually, metabolic rate is proportional to the size of the animal such that with increasing mass, there is a decrease in oxygen uptake per unit mass. Edwards (1958) observed this relationship in the midge larvae *Chironomus riparius* (Meigen).

The R.Q. (respiratory quotient) of *C. punctipennis* larvae was 1.00, while that of *C. plumosus* was 1.29, indicating a difference in the metabolic state of both organisms (Table 1). The R.Q. of *C. punctipennis* larvae is a normal R.Q. for carbohydrate metabolism.

Under anoxic conditions, acid production of *C. punctipennis* larvae exceeded that of *C. plumosus* larvae approximately 3.3 times (Table 1). Stahl (1959) reported that *Chironomus* larvae have strong resistance to low oxygen tension and *C. plumosus* larvae can temporarily tolerate anoxic conditions. This is accomplished by establishing a temporary oxygen debt for a few hours (not more than three to four days under natural conditions) during which time only some of the fatty acids are excreted. Hence, an oxygen debt evidently is created in both species in their natural environments and that debt is relieved to some extent by both species excreting some fatty acids under anaerobiosis. However, under natural anoxic conditions, *C. plumosus* larvae have no means by which to finally relieve their entire oxygen debt. On the other hand, *C. punctipennis* larvae perform diurnal vertical migrations to the well-oxygenated surface waters where they rid themselves of the oxygen debt.

*C. punctipennis* larvae possess a unique behavior that allows them to

avoid the anoxic conditions of the lake bottom part of the time on a daily basis. The diurnal vertical migration behavior of *C. punctipennis* larvae may be a response to oxygen availability. *C. plumosus* larvae do not possess a means by which they can withstand or escape anoxic conditions for prolonged periods.

The data collected during this investigation compared very favorably with those collected by Ransom et al. (1970). However, those data collected during the earlier investigation were 10 to 15% higher for all categories listed in Table 1, except R.Q. The R.Q.'s in the earlier investigation were about 15% lower than for this investigation. These differences in data are understandable when one notes the differences in temperature at which the data were collected. Data were collected at 30 C during the earlier investigation and at 25 C during the present investigation. The current investigators intended to collect data at both 25 C and 30 C, but they failed to be able to hold the apparatus at 30 C for the required time. Therefore, they readily acknowledge that a good comparison between the two investigations is not possible at present. However, that does not negate the fact that, overall they are similar.

## Literature Cited

Bullock, T. H. 1955. Temperature adaptation in poikilothermic animals. Biol. Rev. 30:311–342.

Deonier, C. D. 1943. Biology of the immature stages of the Clear Lake gnat (Diptera, Culicidae). Entomol. Soc. Am. Annals. 36:383–388.

Edwards, R. W. 1958. The relation of oxygen consumption to body size and to temperature in the larvae of *Chironomus riparius* (Meigen). J. Exp. Biol. 35:383–395.

Fox, H. M., F. R. S. Taylor, and A. E. H. Taylor. 1955. The tolerance of oxygen by aquatic invertebrates. Proc. Roy. Soc. London B. 143:214–225.

Fromm, P. O. 1965. Physiological considerations in studies of the action of pollutants on aquatic animals, p. 316–319. *In* Biological problems in water pollution, third seminar. Public Health Serv. Publ. 999-WP-25.

LaRow, E. J. 1968. A persistent diurnal rhythm in *Chaoborus* larvae. I. The nature of the rhythmicity. Limnol. Oceanog. 13:250–256.

Main, R. A. 1953. A limnological study of *Chaoborus* (Diptera) in Hall Lake, Washington. M.S. Thesis, Univ. Washington, Seattle, 106 p.

Prosser, C. L. 1955. Physiological variation in animals. Biol. Rev. 30:229–262.

Ransom, J. D. 1969. Community structure of benthic macroinvertebrates and related physiochemical conditions in Keystone Reservoir, Oklahoma. Ph.D. Thesis, Oklahoma State Univ., Stillwater.

Ransom, J. D., F. L. Rainwater, and C. C. Beames. 1970. A note on the metabolism of two Dipteran larvae, *Chaoborus punctipennis* and *Chironomus plumosus*. Proc. Okla. Acad. Sci. 49:215–217.

Stahl, J. B. 1959. The developmental history of the *chironomid* and *Chaoborus* faunas of Myers Lake. Invest. Indiana Lakes and Streams. 5:47–102.

Stahl, J. B. 1966. The ecology of *Chaoborus* in Myers Lake, Indiana. Limnol. Oceanog. 11(2):177–183.

Umbreit, W. W., R. H. Burris, and J. F. Stauffer. 1957. Manometric techniques. Burgess Publ. Co., Minneapolis, Minnesota. 387 pp.

Wood, K. G. 1956. Ecology of *Chaoborus* (Diptera:Culicidae) in an Ontario lake. Ecology 37:639–643.

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# Additions to the Reptile Fauna of El Salvador

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ABSTRACT

Three species of reptiles are reported for the first time from El Salvador: *Coleonyx elegans* Gray, *Tropidodipsas sartorii* Cope, and *Dryadophis melanolomus* (Cope).

The herpetofauna of El Salvador was first summarized by Mertens (1952). Additional records were provided by Uzzell and Starret (1958), Nelson and Hoyt (1961), and Hoyt (1964). Recently, Hidalgo (1979, 1980a, b, c) has added seven snakes and one lizard to the previously known list of species. The species included here have not been previously recorded from El Salvador. Accounts of these species follow.

Abbreviation for the specimens included in this report are: CG = Carlos Guillén Collection; KU = The University of Kansas Museum of Natural History.

## ACCOUNTS OF SPECIES

### *Coleonyx elegans* Gray

This lizard inhabits low and moderate elevations from Mexico south to Belize and Guatemala (Smith and Taylor, 1950; Henderson and Hoevers, 1975; Stuart, 1963). Peters and Donoso-Barros (1970) also recorded this species from Honduras, although, in a more recent survey, Meyer (1969) and Meyer and Wilson (1973) did not find it there. Until recently, *C. mitratus* (Peters) was the only member of the genus known to occur in El Salvador. On the night of 13 November 1973, one *C. elegans* (KU 183994) was collected by Carlos Guillén in northwestern El Salvador, Hacienda San Diego, 7 km S Metapan, Departamento de Santa Ana, 470 m. This region is very dry (Tropical Dry Forest formation of Holdridge, 1975), with abundant pasture land, low thickets of scrub vegetation, and an extensive dry forest covering old lava beds.

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The male specimen has: supralabials 7-7; infralabials 6-6, first triangular; preanal pores total 9; mental subtriangular; 7 scales bordering posterior margins of upper prenasals between nostrils; claws of forefeet completely concealed by large, terminal sheath scales, those of the hindfeet with only the tips exposed. The color in life was: dorsal ground color cream; dorsum of body and anterior part of tail each with four triads consisting of a narrow cream transverse band, bordered on both sides by broad dark brown transverse bands; posterior part of tail having only dark brown rings; nape with a V-shaped cream band edged on both sides by dark brown. Total length 124 mm; tail length 57 mm.

A comparison of this specimen with others from Guatemala (KU 55869, 144922, 157085), Belize (KU 157084), and Yucatan (KU 157096–99, 157100–08) and Chiapas (KU 94043), Mexico, reveals no notable differences in the Salvadoran specimen. Furthermore, the above description agrees well with the diagnostic characters given by Dixon (1970), Klauber (1945), Peters and Donoso-Barros (1970), and Stuart (1963) for *C. e. elegans*. Other reptiles existing sympatrically with this species in the dry forest include *Cnemidophorus motaguae, C. deppei deppei, Mabuya mabouya, Gymnophthalmus speciosus, Anolis lemurinus, Micrurus nigrocinctus, Dryadophis melanolomus laevis, Oxyrhopus petola sebae,* and *Crotalus durissus durissus.*

*Tropidodipsas sartorii* Cope

This snake ranges from San Luis Potosi and Chiapas, Mexico, south through Guatemala, on both slopes, to Honduras and Nicaragua (Peters and Orejas-Miranda, 1970; Meyer, 1969; Villa, 1971). One specimen (CG 31) was collected on 13 February 1973 in the region of Laguna San Diego, Hacienda San Diego, 6 km S Metapan, Departamento de Santa Ana, 470 m. The vegetation in this region consists of low scrub forest, pastures, and primary dry forest surrounding the lake. Holdridge (1975) classified this area as Tropical Dry Forest. Two other specimens (KU 183973–74) come from San Salvador, Departamento de San Salvador.

All of the Salvadoran specimens are females and have the following characteristics: ventrals 182, 180, 188; anal plate entire; subcaudals 62(2), 66; dorsal scales feebly keeled, in 17 rows; supralabials 8-7, 7-7(2), with 4th and 5th entering orbit; infralabials 7-8, 8-9(2), with 1st pair in contact behind mental; 2 pairs of chin shields; preoculars 2-2 in two (loreal entering orbit in one of these, passing between preoculars), 1-1 in one (loreal entering orbit, passing below preocular on both sides); postoculars 2-2; temporals 1+2; total length 598, 553, 403 mm; tail length 133, 105, 86 mm. In formalin one specimen (CG 31) has 20 pale red rings on the body and 8 on the tail, all are complete around the body, except nuchal ring, the one immediately anterior to the anus, and those on the tail; interspaces between red rings and venter dark brown. Two (KU 183973–74) have 15 to 19 pale yellow

rings on the body, and 5 or 6 on the tail; the yellow rings are complete, except for one specimen in which three rings on the body are incomplete, interspaces between the pale rings dark brown.

Smith (1943) provided scale counts and color patterns for the two Central American subspecies of *Tropidodipsas sartorii*. He characterized *T. s. sartorii* as having incomplete pale red rings and *T. s. annulatus* as having complete pale yellow rings. Both subspecies are apparently represented in the El Salvador material—CG 31 fits the description of *T. s. sartorii*, whereas KU 183973–74 fit that of *T. s. annulatus*. The geographic variation of *T. s. sartorii* and *T. s. annulatus* is not known. Color and ventral extent of body rings are the only characters that distinguish them. Because these characters seem to be variable geographically and individually, the validity of these subspecies is questionable.

### *Dryodophis melanolomus* (Cope)

This snake is widespread at low and moderate elevations from Mexico through Central America to Panama (Peters and Orejas-Miranda, 1970). On 12 February 1973, the first Salvadoran specimen (CG 28) was found by Carlos Guillén in a grassy flat field bordering Laguna San Diego at Hacienda San Diego, 6 km S Metapan, Departamento de Santa Ana, 470 m. This region is in the Tropical Dry Forest formation of Holdridge (1975).

The specimen is a female and has: loreals 1-1; preoculars 1-1; postoculars 2-2; temporals 2+3; supralabials 9-9, with 4th, 5th and 6th entering orbit; infralabials 10-10; 2 pairs of chin shields; dorsal scale formula 17-17-15; dorsal scales smooth; ventrals 186; anal plate divided; subcaudals 132; total length 831 mm; tail length 266 mm. The color in life was: dorsum dark brown, with 19 narrow pale gray crossbands anteriorly on the first quarter of body; the pale crossbands are separated by broader dark brown crossbands; all crossbands reach tips of ventrals; dorsum of head dark brown; supralabials, temporals, infralabials, chin shields, gulars, venter, and undersurface of tail creamy white.

The Salvadoran specimen can be assigned to *Dryadophis m. laevis*, as defined by Peters and Orejas-Miranda (1970) and Stuart (1941). Two species of the wide-ranging genus *Dryadophis* are now known from El Salvador. *Dryadophis melanolomus* occurs at low elevations (470 m), and *D. dorsalis* inhabits higher elevations (600–1900 m).

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## Literature Cited

Dixon, J. R. 1970. *Coleonyx* Gray. Cat. Amer. Amph. Rept. 95.1.

Henderson, R. W., and L. G. Hoevers. 1975. A checklist and key to the amphibians and reptiles of Belize, Central America. Milwaukee Public Mus., Contrib. Biol. Geol. 5:1–63.

Hidalgo, H. 1979. Range extension of the snake, *Sibon anthracops* (Cope), in El Salvador. Herp. Rev. 10(3):103.

Hidalgo, H. 1980a. *Enyaliosaurus quinquecarinatus* (Gray) and *Leptodeira nigrofasciata* Gunther in El Salvador. Herp. Rev. (in press).

Hidalgo, H. 1980b. Occurrence of *Pelamis platurus* (Linnaeus) in El Salvador. Herp. Rev. (in press).

Hidalgo, H. 1980c. New additions to the snake fauna of El Salvador. Herp. Rev. (in press).

Holdridge, L. R. 1975. Mapa ecologico de El Salvador. Ministerio de Agricultura y Ganaderia, Direccion General de Recursos Naturales Renovables, San Salvador, El Salvador, C.A. 98 pp.

Hoyt, D. L. 1964. The rediscovery of the snake *Leptophis modestus*. Copeia 1964(1):214–215.

Klauber, L. M. 1945. The geckoes of the genus *Coleonyx* with descriptions of new subspecies. Trans. San Diego Soc. Nat. Hist. 10(11):133–216.

Mertens, R. 1952. Die Amphibien und Reptilien von El Salvador. Abh. Senckenb. Naturf. Ges. 487:1–120.

Meyer, J. R., and L. D. Wilson. 1971. Taxonomic studies and notes on some Honduran amphibians and reptiles. Bull. So. Calif. Acad. Sci. 70(3):106–114.

Meyer, J. R. 1969. A biogeographic study of the amphibians and reptiles of Honduras. Ph.D. Thesis, Univ. Southern California, 589 pp.

Nelson, C. E., and D. L. Hoyt. 1961. New Central American records for *Rhinophrynus dorsalis*. Herpetologica 17(3):216.

Peters, J. A., and R. Donoso-Barros. 1970. Catalogue of the Neotropical Squamata: Part II. Lizards and amphisbaenians. Bull. U.S. Nat. Mus. 297:1–293.

Peters, J. A., and B. Orejas-Miranda. 1970. Catalogue of the Neotropical Squamata: Part I. Snakes. Bull. U.S. Nat. Mus. 297:1–347.

Smith, H. M. 1943. Summary of the collections of snakes and crocodilians made in Mexico under the Walter Rathbone Bacon Traveling Scholarship. Bull. U.S. Nat. Mus. 93:393–504.

Smith, H. M., and E. H. Taylor. 1950. An annotated checklist and key to the reptiles of Mexico exclusive of the snakes. Bull. U.S. Nat. Mus. 199:1–253.

Stuart, L. C. 1941. Studies of Neotropical Colubrinae. VIII. A revision of the genus *Dryadophis* Stuart. 1939, Misc. Publ. Mus. Zool. Univ. Michigan 49:1–106.

Stuart, L. C. 1963. A checklist of the herpetofauna of Guatemala. Misc. Publ. Mus. Zool. Univ. Michigan 122:1–150.

Uzzell, T. M., Jr., and P. Starret. 1958. Snakes from El Salvador. Copeia 1958(4):339–342.

Villa, J. 1971. Notes on some Nicaraguan reptiles. J. Herpetol. 5(1–2):45–48.

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# A Record of the Alligator Snapping Turtle, *Macroclemys temmincki* (Testudines: Chelydridae), in Kansas

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ABSTRACT

Description of a record of *Macroclemys temmincki* in the Cottonwood River at Emporia, Kansas, is given, with comments on the occurrence of the turtle in the state.

There are only two records, with accompanying preserved remains, of the occurrence of the alligator snapping turtle, *Macroclemys temmincki*, in Kansas, according to Collins (1974); one from the Arkansas River in Cowley County and the other from the Neosho River drainage in Lyon County. The Lyon County record has never been described; this note gives details on the specimen.

On February 21, 1967, two young men, Rick Christie and J. M. McDaniel, found a large alligator snapping turtle in the Cottonwood River at Emporia. It was at the shore, just below Soden's Dam at the south end of Commercial Street. The turtle was dead and beginning to decompose. The skull and shell were salvaged and placed in the vertebrate museum at Emporia State University, cataloged as H2237. The specimen, a male, weighed 54 pounds, has a carapace length of 55.8 cm, carapace width of 44.1 cm, and plastron length of 36.0 cm.

Conversations with local fishermen over the years reveal that they can distinguish between two kinds of snapping turtles they catch in the Cottonwood River. One, to which they apply the appellation "mossy back," is described as a large snapping turtle with a pronounced beak and prominent carapace ridges, as distinct from other large, rather smooth-shelled snappers. Thus, the alligator snapping turtle, although not often in collections, apparently does turn up occasionally on fishing lines. Its predilection for bottoms of large, deeper water courses keeps it from discovery through conventional collecting techniques.

Hall and Smith (1947) reported seven separate collections of the alligator snapping turtle from the Neosho River in Cherokee County and one from Neosho County. One specimen was taken from the Cottonwood River in

Chase County and two from the Arkansas River drainage in Butler and Sedgwick Counties. There were skeletal remains of some of these at one time, but a number of the records are from the latter part of the past century, and, apparently, the specimens have been lost. This turtle should be expected in any of the main channels of the Cottonwood-Neosho system, as well as large streams which make up the Arkansas River drainage.

## Literature Cited

Collins, J. T. 1974. Amphibians and reptiles in Kansas. Univ. Kansas Mus. Nat. Hist. Publ. Ed. Ser. 1:1–283.

Hall, H. H., and H. M. Smith. 1947. Selected records of reptiles and amphibians from southeastern Kansas. Trans. Kansas Acad. Sci. 49(4):447–454.

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# A Natural Hybrid Fish, *Percina maculata* × *P. caprodes*, from Kansas

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We report a hybrid darter, *Percina maculata* × *P. caprodes*, from the Middle Branch of Mill Creek in Sec. 35, T.12S, R.10E, Wabaunsee County, Kansas, collected on 12 April 1974. Four species of darters occur in Kansas River Basin (Cross, 1967): the blackside darter, *P. maculata*; the logperch, *P. caprodes*; the orangethroat darter, *Etheostoma spectabile*; and the johnny darter, *E. nigrum*. The specimen reported (KU 18426) has characteristics

Table 1. Standard length, dimensions (as thousands of standard length), and counts obtained from samples of 15 *Percina maculata*, and 15 *P. caprodes*, and the presumed hybrid.

| | *P. maculata*[1] | | | *P. caprodes*[2] | |
|---|---|---|---|---|---|
| | Range | Mean | Hybrid | Mean | Range |
| Standard length | 39.7–69.5 | 52.3 | 68.1 | 66.4 | 43.7–85.0 |
| Predorsal length | 325–382 | 358 | 361 | 326 | 310–350 |
| Caudal peduncle length | 179–211 | 194 | 179 | 174 | 165–187 |
| Head length | 279–309 | 294 | 285 | 279 | 266–311 |
| Snout length | 059–080 | 070 | 078 | 088 | 083–098 |
| Eye length | 058–074 | 067 | 060 | 055 | 047–069 |
| Interorbital width | 025–036 | 031 | 035 | 049 | 045–053 |
| Postorbital length, head | 130–167 | 154 | 147 | 129 | 123–142 |
| Tip of mandibles to union of gill membranes | 109–139 | 125 | 126 | 141 | 122–160 |
| Tip of mandibles to posterior end of maxilla | 074–093 | 086 | 081 | 066 | 059–078 |
| Lateral line scales | 57–67 | 62.5 | 72 | 81.1 | 79–84 |
| Dorsal spines | 12–15 | 13.3 | 15 | 14.3 | 13–16 |
| Dorsal soft-rays | 13–15 | 13.9 | 15 | 15.9 | 15–17 |
| Anal soft-rays | 10–11 | 10.4 | 11 | 10.8 | 10–12 |
| Pectoral rays | 13–14 | 13.5 | 15 | 14.2 | 14–15 |

[1] KU 7447(1), KU 15111(2), and KU 18427(2), all from Mill Creek, Wabaunsee Co., Kansas; KU 8633(5), Wapsipinicon R., Buchanan Co., Iowa; KU 14390(5), Cormorant R., Beltrami Co., Minnesota.

[2] KU 2963(5) and KU 8262(10) from Mill Creek, Wabaunsee Co., Kansas.

that preclude its identification as any of those species, but it is generally intermediate between *P. maculata* and *P. caprodes* (Table 1). Natural occurrences of this hybrid combination have been reported elsewhere (Schwartz, 1972; Page, 1976).

Mill Creek is the only stream in Kansas in which *P. maculata* is known to occur. We collected both *P. maculata* and *P. caprodes*, as well as the hybrid, there on 12 April 1974. Other hybrid fishes have been found in Mill Creek: *Semotilus atromaculatus* × *Phoxinus erythrogaster* (KU 2947) (Cross and Minckley, 1960:7); *S. atromaculatus* × *Notropis cornutus* (KU 2948); and *Notropis rubellus* × *N. cornutus* (KU 2950, 2958, 8120, 12603).

## Literature Cited

Cross, F. B. 1967. Handbook of fishes of Kansas. Univ. Kansas Mus. Nat. Hist., Misc. Publ. 45. 357 pp.

Cross, F. B., and W. L. Minckley. 1960. Five natural hybrid combinations in minnows (Cyprinidae). Univ. Kansas Mus. Nat. Hist. 13:1–18.

Page, L. M. 1976. Natural darter hybrids: *Etheostoma gracile* × *Percina maculata*, *Percina caprodes* × *Percina maculata*, and *Percina phoxocephala* × *Percina maculata*. Southwestern Nat. 21:145–149.

Schwartz, F. J. 1972. World literature to fish hybrids with an analysis by family, species, and hybrid. Gulf Coast Res. Lab., Mus. Publ. 3. 328 pp.

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# First Record of Long-tailed Shrews (*Sorex*) in Kansas

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ABSTRACT

The first recorded specimen from Kansas of a long-tailed shrew (*Sorex cinereus haydeni*) was collected in Jewell County. Another *Sorex*, unlike typical *S. c. haydeni*, *S. preblei*, or *S. hoyi* was also captured at the same locality.

The long-tailed shrews of the genus *Sorex* are widely distributed throughout North America, from Alaska and arctic Canada, south to 40°N latitude and south along the Sierra Nevada, Appalachian, and Rocky mountains to Central America. On the Northern Great Plains, *Sorex* was known as far south as Nebraska; the masked shrew (*Sorex cinereus haydeni*) was reported by Jones (1964) to be locally common in the northern half of Nebraska, especially in lush riparian and marshy habitats. Choate and Genoways (1966) extended the reported range of the species south in Nebraska to 2.5 miles south and 3 miles east of Crete, Saline County, about 40 miles north of the Kansas border, and suggested that it might be found along the Big Blue River in Kansas.

On 19 October 1980 the senior author collected a juvenile male long-tailed shrew from the SW¼, Sec. 1, T2S, R6W, at the Lovewell Reservoir, Jewell County, Kansas. The specimen (KU 135748) was taken in a grassy field, approximately 100 meters west of the reservoir shore line. External measurements (in mm) of this specimen are as follows: total length, 83; length of tail, 32; length of hind foot, 12; weight, 3.7 grams. Cranial measurements (mm) of the specimen are: condylobasal length, 15.6; cranial breadth, 7.7; interorbital breadth, 3.15; length of maxillary toothrow, 6.05; molariform toothrow length, 3.96; unicuspid toothrow length, 2.22; width across M2–M2, 3.88. Measurements of condylobasal length and cranial breadth are approximations. The specimen is typical of the subspecies *S. c. haydeni* (Van Zyll de Jong, 1980), external and cranial measurements falling within the range of *S. c. haydeni* from Nebraska, Iowa, and Minnesota. *Sorex cinereus haydeni* has been regarded as a subspecies of *S. cinereus*, but recent work by Van Zyll de Jong (op. cit.) indicate that the two taxa are

morphologically distinct, occur sympatrically, and perhaps represent separate species.

Another specimen (KU 135749) of long-tailed shrew was trapped the previous day from the same field. This juvenile female is unusual in several features. Only four unicuspids are present on each side of the upper jaw; the fourth is distinctly smaller than the third. This last unicuspid is larger than the fifth unicuspid and smaller than the fourth unicuspid of a typical *Sorex cinereus*. Several cranial measurements, for example molariform toothrow, unicuspid toothrow, length and width of M2–M2, are smaller than the corresponding measurements for the vast majority of *S. c. haydeni*, and the small size of the animal suggested a possible relationship to *Sorex* (*Microsorex*) *hoyi*. In shrews of the subgenus *Microsorex* the third unicuspid is greatly reduced and not usually visible in lateral view, while the accessory medial tine on the anterior surface of the first upper incisor is very large (Diersing, 1980). In our specimen the accessory medial tine of the first incisor is not enlarged and there is no basis for interpreting the missing unicuspid as a lost third unicuspid.

*Sorex preblei* is also very small, but its closest known occurrence is in eastern Montana (Hoffmann et al., 1969). Bowles (1975) mentioned two unusually small *Sorex* from southwestern Iowa which he provisionally retained in *S. c. haydeni*; the same course seems prudent for this specimen, which we tentatively regard as a case of bilateral dental anomaly in *S. c. haydeni*. The status of these enigmatic small shrews is presently under study by Van Zyll de Jong and Kirkland (in litt.).

## Literature Cited

Bowles, J. B. 1975. Distribution and biogeography of mammals of Iowa. The Museum, Texas Tech Univ. Special Pub. 9:1–184.

Choate, J. R., and H. H. Genoways. 1966. Notes on some mammals from Nebraska. Trans. Kansas Acad. Sci. 69(3–4):238–241.

Diersing, V. E. 1980. Systematics and evolution of the pygmy shrews (subgenus *Microsorex*) of North America. J. Mamm. 61:76–101.

Hoffmann, R. S., P. L. Wright, and F. E. Newby. 1969. The distribution of some mammals in Montana. I. Mammals other than bats. J. Mamm. 50:579–604.

Jones, J. K., Jr. 1964. Distribution and taxonomy of mammals of Nebraska. Univ. Kansas Publ., Mus. Nat. Hist. 14:493–758.

Van Zyll de Jong, C. G. 1980. Systematic relationships of woodland and prairie forms of the prairie shrew, *Sorex cinereus cinereus* Kerr and *S. c. haydeni* Baird, in the Canadian prairie provinces. J. Mamm. 61:66–75.

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# Assessing the Relative Effects of Climate and Technology on Wheat Production in Kansas

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ABSTRACT

A crop-climate-technology model is developed to assess the relative effects of climate and technology on wheat production in eleven counties distributed in different crop reporting districts of Kansas. Monthly and seasonal values of potential evapotranspiration, soil moisture deficit, and precipitation are identified as predictors most significantly associated with yield in all the selected counties. The statistical procedure used in this study allows the regression model to determine the quantitative nature of the relationship between yield and technology without having to pre-specify the values arbitrarily. However, the relationship between yield and technology is assumed to be linear for each of the periods. The impact of technology on yield over time is indicated by fitting a piece-wise technology trend line to the data with discontinuities in 1945, 1955, and 1960.

The model accounts for between 80 and 90 percent of the yield variance in all counties. Climatic variables account for more than 30 percent of the yield variance in the dry sub-humid/semi-arid western and central counties. Therefore, while technology has enhanced wheat yields under adverse climatic conditions in Kansas, it has not overcome all the negative effects of climatic stress on wheat production in the dry sub-humid and semi-arid regions of the state.

In recent years the attention of agronomists and climatologists has focused on the relative roles of climate and technology in crop production. The increasing focus on crop-weather relationship has been prompted by scholars who strongly believe that the abnormal weather conditions of the 1970's are a prelude to a major climatic change. Assessment of climatic risks for crop production requires the development of models which have the capability to appraise the relative roles of climate and technology in explaining yield variance under conditions of varying climatic stress. A careful assessment of the relative roles of climate and technology in crop production

is necessary because there is evidence that, despite the advances made in technology, crop failures can still result from adverse weather conditions. Assessment of the relative roles of climate and technology in explaining yield variance under varying climatic stress is necessary so that precautionary measures can be adopted by government and private agencies to increase grain reserves to meet domestic and international demand for grain during periods of adverse weather conditions.

The relationship between climatic fluctuations and crop production has been investigated by Gilman (1974), Thompson (1975), Decker (1976), and Newman (1978) in recent years. These studies indicate that while technology contributed to increased crop production since the 1940's the consistently high yields during the period 1955 to 1973 were largely attributed to extremely favorable weather conditions. This would seem to be true, if it were statistically proven that despite the improvements made in the technology of food production, the low to moderate yields prior to and after 1955 to 1973 were due to short-term climatic fluctuations.

The role of technology in improving wheat production since the 1950's cannot be overlooked. Between 1950 and 1972 the "price of new capital improvements remained favorable" and farmers increased their use of fertilizers, pesticides and farm machinery, according to Heady (1976). Yet, the exact impact of technology on annual production of wheat under varying environmental conditions is not clearly understood. McQuigg (1975) is convinced that, in general, technology can account for 70 to 80 percent of the total variance in wheat production, while weather can account for 12 to 18 percent of the variance. However, these conclusions are based on sample productivity data which were analyzed for a period of years using state averages of yield and weather. Nevertheless, Hass, Willis and Bond (1974) and Heady (1976) are convinced that the contributions of technology such as the increased use of fertilizers, improved varieties and strains of wheat, extension of irrigation, use of pesticides, mechanization and other cultural practices are effective in overcoming limitations imposed by climate in such dry sub-humid and semi-arid regions. One of the methods available to assess the role of technology on crop production is to develop a reliable crop-weather-technology model for predicting yields on a regional basis in any of the Great Plain states where climate varies from sub-humid to semi-arid conditions. The purpose of this paper is to examine the regional variations in wheat climate-technology relationships in Kansas using a yield-climate-technology model.

## The Study Area

The state of Kansas has been selected for this study since it is the leading state in both grain production and acreage planted in wheat (Reitz, 1976). Not only do weather differences cause great year-to-year variations in an-

Table 1. Wheat Yields in Cheyenne County and Atchison County, Kansas.

| Cheyenne County | | Atchison County | |
|---|---|---|---|
| Year | Yield (bu/acre) | Year | Yield (bu/acre) |
| 1965 | 11.0 | 1965 | 21.0 |
| 1966 | 18.0 | 1966 | 30.0 |
| 1967 | 16.0 | 1967 | 24.0 |
| 1968 | 16.0 | 1968 | 37.0 |
| 1969 | 26.0 | 1969 | 29.0 |
| 1970 | 25.0 | 1970 | 28.0 |
| 1971 | 15.0 | 1971 | 39.0 |
| 1972 | 21.0 | 1972 | 33.0 |
| 1973 | 33.0 | 1973 | 30.0 |
| 1974 | 26.1 | 1974 | 27.4 |

Source: Kansas Crop & Livestock Reporting Service, 1978, "Wheat Acreage and Production by Counties."—Kansas State Board of Agriculture, USDA.

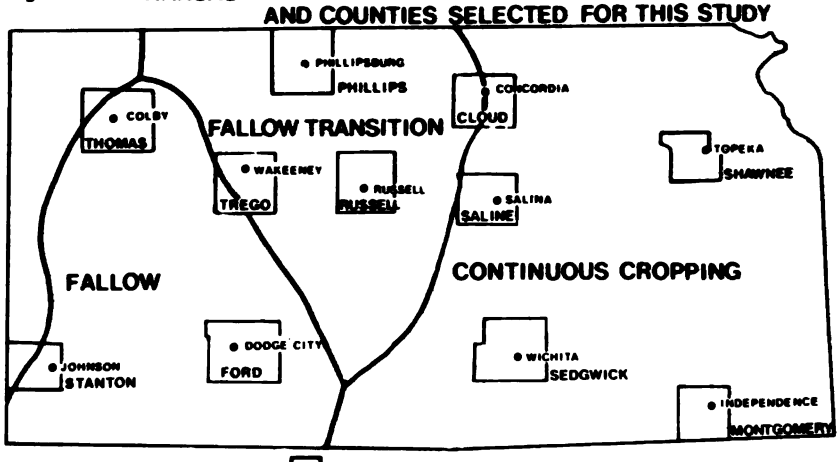
nual wheat production, but climatic differences within the state result in considerable variations in the regional production of wheat. Table 1 shows these climatic-yield variations on a regional basis in Kansas by comparing the wheat yields on continuously-cultivated fields in both Cheyenne County, located in the semi-arid west, and Atchison County, located in the humid east.

To combat the effects of low moisture levels in the western counties many farmers have resorted to either irrigation or to the practice of leaving a portion of the farm fallow each year. Preliminary examination of the regional distribution of cropping practices (Fig. 1) suggests that both summer fallow and irrigated cropping are prevalent in twenty-one western counties. In the extreme northwest, where Cheyenne County is located, the semi-arid conditions permit the practice of crop rotation involving fallow-wheat-millet or other small grain farming without the aid of irrigation. In Stanton County in southwestern Kansas, twenty-five percent of wheat acreage was irrigated in 1977, to combat moisture stress (Kansas Crop & Livestock Reporting Service, 1978). In the moist sub-humid east, almost all of the wheat is harvested from fields that are continuously cultivated. Annual values of potential evapotranspiration and precipitation are used in Figure 2 to indicate the regional variations in climate.

## Procedure

Data on wheat yields and weather from 1921 to 1977 were analyzed for eleven counties in Kansas, shown on Figure 1, to derive a yield-climate-technology model. Annual reports of the Kansas Crop and Livestock Reporting Service were used to obtain data on wheat acreage and production by counties for the 57 years. Weather data on mean monthly minimum and

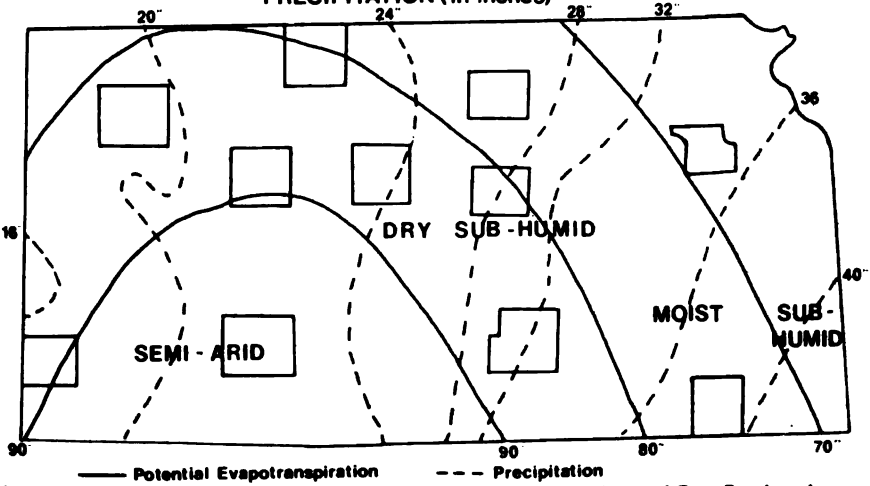
Figure 1 KANSAS: *REGIONAL DISTRIBUTION OF CROPPING PRACTICES AND COUNTIES SELECTED FOR THIS STUDY




● Weather Stations ☐ Counties Selected for This Study

*Source: B.W. Greb, D.E. Smika, N.P. Woodruff, and C.J. Whitfield (1974). Summer Fallow in Central Great Plains, In. SUMMER FALLOW IN THE WESTERN UNITED STATES. Conservation Research Report #17, Agricultural Research Service, USDA, pages 51-85

Figure 2 KANSAS: *MEAN ANNUAL CLASS A PAN EVAPORATION AND PRECIPITATION (in inches)




—— Potential Evapotranspiration - - - Precipitation

*Source: A.L. Black and R.S. Whitney (1966). Phosphorous Status of Horizons of Four Benchmark Loessial Soils of Central Great Plains Region. SOIL SCI. SOC. AMER. PROC. 30 259-262

maximum temperatures and monthly precipitation totals for the stations used in this study, as indicated in Figure 1, were purchased on microfiche from the National Climatic Center in Asheville, North Carolina.

To develop a reliable predictive model it is necessary to minimize the condition of multicollinearity existing in weather variables. In most yield-weather models weather variables are not truly independent, but it is possible to minimize this problem by using both weather variables and transformed weather variables, as suggested by McQuigg (1975). These transformed weather variables are potential evapotranspiration, actual evapotranspiration, and soil moisture deficit, which are computed by using the water balance procedure.

Thornthwaite's water balance procedure (1948) is not used to compute values of potential evapotranspiration (PE), because it has been found to underestimate PE values, especially in arid regions (Omar, 1968). Instead, the Papadakis formula (Papadakis, 1966), which holds up well in tests of various estimates of PE, is used to compute monthly values of potential evapotranspiration. Unlike Thornthwaite, Papadakis derives the monthly PE by computing the midday saturation deficit from values of average minimum and maximum monthly temperatures. The most effective humidity variable to express this deficit is vapor pressure, since it provides both an absolute value of the deficit and direct relationships between vapor pressure and temperature.

According to the Papadakis method, $PE = 0.5625(e_{ma} - [e_{mi} - 2])$ where $e_{ma}$ = saturation vapor pressure in millibars, corresponding to average daily maximum temperature; $e_{mi} - 2$ = saturation vapor pressure in millibars corresponding to the average daily minimum minus 2 degrees Celsius. Appropriate values of $e_{ma}$ and $e_{mi}$ can be obtained from tables for corresponding temperatures. Substracting 2 from the monthly mean minimum temperature allows for the fact that some evapotranspiration takes place at low temperatures, as long as the air is not saturated. It is therefore, the saturation deficit, represented by the difference between mean minimum temperature and dew point, that is used in the formula. Except for computing PE, however, I use Thornwaite's water-balance procedure involving a decreasing soil moisture availability curve and a 300-millimeters soil moisture storage capacity to compute actual evapotranspiration and soil moisture deficit. Potential evapotranspiration, actual evapotranspiration, soil moisture deficit, precipitation, mean monthly minimum and maximum temperatures and technology variables are used in the initial screening to generate the model.

The problem inherent in studies of yield-climate-technology relationships is the difficulty of modeling the technology trend. Often the technology trend consists of one or more linear trend lines of similar or dissimilar slopes connected to each other along natural breaks. Assumptions on the number

of trends and the time periods representing the technology trend are based on well-documented evidence on the introduction, availability and the application of various technological inputs to increase agricultural productivity over time. However, the common practice of assigning arbitrary values to show the impact of technology on yield over time can produce erroneous results. Often arbitrary values are assigned to indicate slow or rapid increases in yields for different periods by merely surveying the trends in yield over time (Thompson, 1966). Moreover, a piece-wise trend line is fitted to the data with breaks rather than discontinuities.

The precise nature of the relationship between technology and yield is determined statistically without having to pre-specify the values arbitrarily. However, the technology trend is represented in four steps, each step consisting of a time period when wheat yields increased at a rate corresponding to a variety of technological inputs. The four periods are: 1921–1945; 1946–1955; 1956–1960; and 1961–1977. To overcome the difficulty of separating different types of technological inputs, all the technological factors are aggregated by using time as a proxy variable of technology. The nature of the impact of technology on yield over time is determined by computing independent intercepts and slopes for each of the periods so that the impact of technology of one period does not affect yields on another period. The relationship between technology and yield is assumed to be linear for each of the periods. Therefore, the quantitative nature of the relationship between technology and yield plus the nature of the breaks or discontinuities in the trend line, are captured statistically by observing the shifts in the computed intercepts and changes in the slopes for each period.

The first period presumably commenced during the early twenties and continued through the 1930's when dramatic increases in wheat yields in Kansas were associated with a rapid increase in the acreage under summer fallow (Hass, 1974 and Kuska, 1956). The second period of increased yields commenced just after World War II when large quantities of nitrogen were released from war munitions to the farmers at low prices (McQuigg, 1975). Another upward trend in wheat yields commenced in 1956 when farmers began to make greater use of not only high quality chemical fertilizers but also of hybrid food strains and mechanical farm equipment to cultivate wheat. Schneider and Mesirow (1977), emphasized that "since 1955 the use of technological aids, such as chemical fertilizer, certain hybrid food strains, and further developments in mechanical farm equipment, mushroomed." In addition, the government price support in the fifties made it more profitable to apply higher levels of technology to the land that remained under cultivation (Heady, 1976). Finally, the fourth period (1961–1977) is associated with pronounced improvements in machinery to plant and harvest wheat more efficiently. Moreover, government price support programs, which helped to maintain the price of grain artificially high, also contributed to

higher yields. Land of high productive capacity remained under cultivation and the high price of wheat made it profitable for farmers to apply high levels of technology to these highly productive acres planted (McQuigg, 1975). According to Heady (1976), the utilization of fertilizers, pesticides, and farm machinery, which began in the 1950's, began to increase every year. He also indicates that the use of fertilizer increased by "276 percent between 1950 and 1972." The overall effect of all these inputs was a sudden rise in wheat yields in the United States since 1960, as indicated by Newman (1978) and Thompson (1978). The 1960's also inaugurated a period of irrigated wheat farming in the southwestern counties. In Stanton and Ford counties only 20 percent and 10 percent, respectively, of the wheat acreage was under irrigation during the year 1960 (Kansas Crop and Livestock Reporting Service, 1978). This was roughly 14,000 acres in Stanton County and 5,000 acres in Ford County. By the year 1977, the irrigated wheat acreage had increased to 41,000 acres in Stanton, and 5,000 acres in Ford.

Once these four periods were identified, a piece-wise trend line was fitted to the data. The quantitative values of both the discontinuities and the slopes for each of the periods were captured by observing the shifts in the intercepts and changes in the slope for the respective periods. Regression analysis between wheat yields, climate and technology was performed to identify the variables most closely associated with growth in all counties selected for this study. Errors due to multicollinearity in weather variables, and inaccuracies arising from assigning arbitrary values to model the technology trend line were minimized to generate a reliable yield-climate-technology model.

The initial step in generating this model involved computing a sequence of multiple linear regression equations in a stepwise manner for all counties. The independent variables consisted of monthly and seasonal values of potential evapotranspiration (PE), actual evapotranspiration (AE), AE/PE, soil moisture deficit, mean monthly minimum and maximum temperatures, and precipitation. The stepwise multiple correlation allows one of the independent variables to do all the explanation it can of the dependent variable and permits the other variables in order of their relative importance to go to work on that portion of the variation left unexplained by the preceding variable or variables. This permits the identification of the variable or variables that explain, in succession, most of the variation in wheat yields. The resulting evaluation of yields is expressed as a linear function of eight climatic variables and eight technology variables, as indicated in the following form:

$$y = a_0 + \Sigma a_i X_i$$

Where $y$ = annual yield of winter wheat, expressed in bushels per acre
$X_1$ = technology 01, intercept for the period 1921–1945

$X_2$ = technology 1, slope for the period 1921–1945
$X_3$ = technology 02, intercept for the period 1946–1955
$X_4$ = technology 2, slope for the period 1946–1955
$X_5$ = technology 03, intercept for the period 1956–1960
$X_6$ = technology 3, slope for the period 1956–1960
$X_7$ = technology 04, intercept for the period 1961–1977
$X_8$ = technology 4, slope for the period 1961–1977
$X_9$ = pre-season soil moisture deficit, August to October
$X_{10}$ = winter precipitation, November to February
$X_{11}$ = mean maximum temperature for March
$X_{12}$ = March precipitation (departure from the mean for the period 1921–1977)
$X_{13}$ = soil moisture deficit for April
$X_{14}$ = potential evapotranspiration for May
$X_{15}$ = May precipitation (departure from the mean for the period 1921–1977)
$X_{16}$ = June precipitation (departure from the mean for the period 1921–1977)
$a_0$ = constant
$a_1 \ldots a_{16}$ = coefficients associated with the independent variables.

## Results and Discussion

Table 2 illustrates the results generated by the yield-climate technology model for eleven counties in Kansas. The F-ratio (0.01 level of significance) which is calculated with respect to the computed coefficients ($R^2$), indicates a high degree of association between climate/technology and winter wheat yields in Kansas. The coefficient of determination ranged between 0.80 to 0.90 at all locations, except for Stanton County. The standard error of the estimate ranged from 3.4 bushels to 4.7 bushels per acre, while the standard deviation of actual yields varied between 7.2 bushels to 10.0 bushels per acre. The small errors in the absolute values of error prediction implies that the model is reliable for predicting wheat yields in Kansas fairly accurately. In fact, Nelson and Dale (1978) compared the magnitude of the absolute values of error prediction to evaluate the predictive ability of four weather and corn yield regression models for Indiana. Thus, the model developed in this study can be used effectively to assess the relative effects of climate and technology on wheat production in Kansas.

An examination of the contribution of independent variables to yield variability reveals that technological factors account for roughly 55 to 75 percent of the yield variance. These values are less than the 70 to 80 percent of the total variance that technology was supposed to account for as suggested by McQuigg (1975). It is possible that by using an appropriate piece-wise tech-

Table 2. *F-ratio (F), Standard error of estimate (S.E.), standard deviation of yield (S.D.) and $R^2$ for multiple regression between the independent variables and winter wheat yield for selected counties in Kansas (1921–1977).

| Selected counties | | $R^2$, S.E., S.D., and F. for the full model | | | | $R^2$ between technology and yield | $R^2$ between climate and yield | $R^2$ between pre-season soil moisture deficit ($X_9$) and yield | $R^2$ between April soil moisture deficit ($X_{13}$) and yield |
|---|---|---|---|---|---|---|---|---|---|
| | | $R^2$ | S.E. | S.D. | F. | | | | |
| Montgomery | C | 0.90 | 3.4 | 9.2 | 24.2 | 0.58 | 0.32 | 0.01 | 0.00 |
| Shawnee | C | 0.81 | 3.6 | 7.2 | 11.8 | 0.69 | 0.12 | 0.05 | 0.01 |
| Cloud | C | 0.85 | 4.2 | 9.4 | 15.7 | 0.57 | 0.28 | 0.05 | 0.01 |
| Saline | C | 0.82 | 3.6 | 7.3 | 12.4 | 0.45 | 0.37 | 0.14 | 0.01 |
| Sedgwick | C | 0.80 | 4.4 | 8.4 | 10.8 | 0.46 | 0.34 | 0.00 | 0.09 |
| Russell | FT | 0.83 | 4.0 | 8.3 | 13.3 | 0.27 | 0.56 | 0.17 | 0.11 |
| Phillips | FT | 0.90 | 3.6 | 10.0 | 25.9 | 0.75 | 0.15 | 0.10 | 0.03 |
| Trego | FT | 0.80 | 4.9 | 9.4 | 10.8 | 0.33 | 0.47 | 0.13 | 0.06 |
| Ford | F | 0.82 | 4.6 | 9.3 | 12.3 | 0.50 | 0.32 | 0.12 | 0.05 |
| Stanton | F | 0.79 | 4.7 | 8.8 | 10.2 | 0.52 | 0.27 | 0.07 | 0.10 |
| Thomas | F | 0.86 | 4.4 | 9.9 | 16.2 | 0.44 | 0.42 | 0.12 | 0.05 |

* Significant at 0.01 level (N = 57). C—Continuous Cultivation. FT—Fallow Transition. F—Fallow.

nology trend line, the yield variability attributed to climatic factors has been strengthened in relation to the technological factors. A high degree of association between yield and technology existed during the period 1956 to 1960, although technological improvements and cultural practices, such as the practice of summer fallow, seemed to have had some positive effects on wheat yields in the western semi-arid and eastern moist-sub-humid counties prior to this period. A close association between yield and technological improvements also existed in the 1960's, as indicated by the above analysis. Nevertheless, the effectiveness of technology, except irrigation, to enhance or maintain high wheat yields is limited under conditions of climatic stress, as indicated in Table 2.

The climatic factors accounted for a greater percentage of yield variance than has been previously suggested by McQuigg (1975). Of the climatic variables, soil moisture deficit accounts for a large percentage of the yield variance, as indicated in Table 2. Pre-seasonal soil moisture deficit ($X_9$) accounted for between 7 to 18 percent of the yield variance in the western counties where summer fallow is practiced to overcome the limitations imposed by limited soil deficit. Soil moisture for April ($X_{13}$) is also found to be associated with wheat yield in the western and central regions of Kansas. Overall, these two soil moisture deficit variables ($X_9$ and $X_{13}$) explain more than 40 percent of the yield variance accounted for by all the climatic variables. The importance of soil moisture for cultivation in the summer fallow

Table 3. Regression coefficients for technology and climatic variables for selected counties in Kansas.

| *Variables | Counties | | | | | |
|---|---|---|---|---|---|---|
| | Mont-gomery | Cloud | Sedgwick | Russell | Ford | Stanton |
| Technology 1 ($X_2$) | 00.0881 | 00.1126 | 00.0298 | 00.1392 | 00.0918 | 00.3921 |
| Technology 02 ($X_3$) | −33.5198 | −0.2895 | 1.9086 | −5.5185 | 6.2911 | 33.2398 |
| Technology 2 ($X_4$) | 1.3299 | 0.0857 | 0.0150 | 0.02562 | −0.1391 | −0.7655 |
| Technology 03 ($X_5$) | −56.9456 | −18.2403 | −34.8656 | 40.2430 | −21.3315 | −97.4066 |
| Technology 3 ($X_6$) | 1.7911 | 0.6784 | 1.1621 | −1.0036 | 0.7368 | 3.0744 |
| Technology 04 ($X_7$) | 2.0205 | −6.5193 | 11.4992 | −23.8735 | −9.1383 | 19.2053 |
| Technology 4 ($X_8$) | 0.3251 | 0.5468 | 0.0858 | 0.7113 | 0.5233 | −0.0241 |
| Pre-season soil moisture deficit ($X_9$) | 0.0708 | −0.3465 | −0.0898 | −0.5050 | −0.7846 | −0.5899 |
| Winter precipitation ($X_{10}$) | −0.2370 | 0.5816 | −0.1160 | 0.8170 | 1.4339 | 0.7866 |
| Maximum March Temperature ($X_{11}$) | −0.2718 | −0.1883 | −0.2632 | −0.3206 | −0.3851 | −0.1591 |
| March precipitation ($X_{12}$) | −0.4601 | 0.7176 | 0.1625 | 0.9331 | −0.0659 | 0.7272 |
| April soil moisture deficit ($X_{13}$) | −0.3929 | 0.5454 | −1.6519 | −0.3085 | −1.1002 | −1.7617 |
| May potential evapo-transpiration ($X_{14}$) | −0.8810 | −2.9933 | 0.7331 | −1.2835 | −1.2248 | −0.8005 |
| May precipitation ($X_{15}$) | −0.3021 | −0.0959 | −0.2952 | 0.0750 | 0.0567 | 0.20441 |
| June precipitation ($X_{16}$) | −1.0962 | −0.6721 | −0.5608 | −0.3176 | −0.2245 | −0.0981 |
| Constant | 32.5820 | 34.6538 | 27.7105 | 40.0292 | 45.3734 | 33.1293 |

* $X_1$ (Technology 01) failed to enter in the equation and is accounted for by the constant ($a_0$).

regions of the northern Great Plains is clearly brought out by Thomas, Army and Cox (1962). They reported that great changes in spring wheat yields are observed there for a given change in soil moisture. In fact, the importance of soil moisture deficit in limiting wheat production cannot be identified if only precipitation is used to explain yield variance in sub-humid and semi-arid regions. Precipitation is not wholly effective for plant growth, since, only the portion of the precipitation which becomes capillary soil moisture is largely associated with growth (C. Manogaran, 1975). It is possible for some growth to occur inrelation to small amounts of rainfall, when soil moisture content is below the field capacity, as during the period from August to October and during April. Under such situations better correlations were found to exist between soil moisture and growth, than between precipitation and plant growth (Zahner and Stage, 1966). The regression weights shown on Table 3 indicate the relative roles played by technology and the

climatic variables in influencing wheat production on a regional basis in Kansas.

Precipitation, however, is found to be associated with yields in the continuously cultivated regions of the eastern counties. Similar trends between precipitation and yield in the continuously cultivated regions of the eastern counties were observed by Thomas, Army and Cox (1962) in their study of spring wheat on the Northern Plains. Precipitation seems to play an important role in influencing yield during May and June, when the rainy period commences. Other precipitation variables ($X_{10}$, $X_{12}$) which show the departure of precipitation from the mean of winter and March, account for only a small percentage of the yield variance. Winter precipitation ($X_{10}$), in particular, correlates poorly with yield, in contrast to the high degree of association that exists between soil moisture conditions during the autumn ($X_9$) and yields. This important relationship between the environmental conditions of the seeding period (August to October) and wheat yields is often ignored when pre-season accumulated precipitation for the period August to March is used as a single variable to explain yield variance.

Of the remaining variables, mean monthly maximum temperature for March ($X_{11}$) and potential evapotranspiration for May ($X_{14}$) are found to be significantly correlated with yield. It is significant to note that potential evapotranspiration for the month of May, rather than for the month of June was found to be significantly associated with yield variability in the study area. These two variables were entered in the model to indicate the importance of thermal conditions for crop production.

## Conclusions

The method employed to model a technology trend line and the procedure adopted to select the climatic variables that are closely associated with winter wheat yields has resulted in the development of a reliable yield-climate-technology model. The study also demonstrates the need to consider regional climatic differences of a state to develop a reliable model to predict yields fairly accurately. This model is equally reliable in predicting yields in both humid and dry environments. Therefore, to predict yields accurately in any of the Great Plain states a single model should incorporate predictors, such as soil moisture deficit, potential evapotranspiration, and precipitation, which are critical in limiting or enhancing wheat yields. Soil moisture deficit is found to be significantly related to wheat yields during some periods, while precipitation is found to be both a limiting and enhancing factor to wheat production during other periods in the same region.

The regional variations in the yield-technology relationships indicate that while technology has enhanced yields under conditions of climatic stress in the study area as a whole, it has not been completely successful in overcoming all the negative effects of adverse climatic conditions on wheat pro-

duction, especially in the semi-arid regions. Therefore it is doubtful that we can have complete faith in the ability of technology to insure against crop failures due to drought, especially in the dry-sub-humid and semi-arid regions of the South and Central Plain states. In fact, the 1974 drought reduced winter wheat production in Texas and Oklahoma, despite the fact that summer fallow and other cultivation practices are adopted by farmers to increase the availability of water for succeeding crop growth (Newman, 1978). The major role played by climate in wheat production in the Great Plains has to be carefully assessed despite advances made in farming technology. Table 2 shows that climate accounts for more than 30 percent of the yield variance in the dry-sub-humid/semi-arid counties of Kansas. Thus, despite the advances which have occurred in technology, there is still the risk of a serious food crisis during periods of major drought in these wheat producing areas.

## Literature Cited

Decker, W., and L. Wayne. 1976. Climate and Food: Climatic Fluctuations and U.S. Agricultural Production. Committee on Climate and Weather Fluctuations and Agricultural Production, National Academy of Sciences, Washington D.C., 212 pp.

Gilman, D. 1974. Paper presented at the 40th meeting of the American Association for the Advancement of Science, San Francisco, February, 27.

Haas, J. J., W. O. Willis, and J. J. Bond. 1974. Summer Fallow in the Western United States. Conservation Research Paper No. 17, Agricultural Research Service, USDA, Washington D.C., 1–50.

Heady, Earl Q. 1976. The Agriculture of the U.S. Scientific American (Food and Agriculture) 235(3):107–127.

Kansas Crop and Livestock Reporting Service. 1978. Wheat Acreage and Production by Counties. Kansas State Board of Agriculture, USDA, Topeka, Kansas. 8 pp.

Manogaran, C. 1975. Acutal Evapotranspiration and the Natural Range of Loblolly Pine. Forest Science, 24(4):339–340.

McQuigg, James D. 1975. Economic Impacts of Weather Variability. Atmospheric Science Department, University of Missouri–Columbia, 256 pp.

Nelson, William L., and Robert F. Dale. 1978. A Method for Testing the Accuracy of Yield Predictions from Weather-Yield-Regression Models for Corn. Agronomy Journal, 70: 734–740.

Newman, James E. 1978. Drought Impacts on American Agricultural Productivity in North American Droughts (ed.) by Norman J. Rosenberg, American Association for the Advancement of Science Selected Symposium 15, Westview Press, Boulder, Colorado, 43–61.

Omar, M. H. 1968. Potential Evapotranspiration in a Warm Arid Climate. Agroclimatological Methods, UNESCO, 347–353.

Papadakis, J. 1966. Climates of the World and Their Agricultural Potentials. Buenos Aires, Argentina. 173 pp.

Reitz, L. P. 1976. Wheat in the United States. Agricultural Information Bulletin No. 36, Agricultural Research Service, USDA, Washington, D.C.

Schneider, S. H., and L. E. Mesirow. 1977. The Genesis Strategy, Plenum Press, New York, 419 pp.

Thomas, J. R., T. J. Army, and E. L. Cox. 1962. Relationships of Soil Moisture and Precip-

itation to Spring Wheat Yields in the Northern Great Plains. Agricultural Research Series, Production Research Report No. 56, USDA, Washington, D.C., 24 pp.

Thompson, L. M. 1975. Weather Variability, Climatic Change, and Grain Production, Science, 188:535–541.

Thompson, L. M. 1969. Weather and Technology in the Production of Wheat in the United States. Journal of Soil and Water Conservation 23:219–224.

Thornthwaite, C. W. 1948. An Approach Towards a Rational Classification of Climate. The Geographical Review, 38:55–94.

Zahner, R., and A. R. Stage. 1966. A Procedure for Calculating Daily Soil Moisture Stress and its Utility in Regressions of Tree Growth on Weather, Ecology, 47:64–74.

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# Kangaroo Rats from the Borchers Local Fauna, Blancan, Meade County, Kansas

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ABSTRACT

A new species of kangaroo rat, genus *Dipodomys*, is reported from the Borchers local fauna. The genus *Etadonomys* is placed in synonomy with *Prodipodomys*. The diagnoses for both *Prodipodomys* and *Dipodomys* are emended to reflect differences between the genera in development of roots, dentine tracts, and anterocone on $P^4$. Physical and biostratigraphic evidence supports placement of the Borchers local fauna in the Blancan land-mammal age.

Two kangaroo rats are present among the mammalian taxa reported from the Borchers local fauna (l.f.). One of these, "*Etadonomys*" *tiheni* (Hibbard, 1943), is a primitive form that lacks or has only slightly developed dentine tracts, and roots that are as well-developed as the crown. Isolated teeth of "*Etadonomys*" are difficult to distinguish from those of *Prodipodomys*. The former taxon continues to be recognized primarily because of characteristics in the development of the temporal fossa and mandibular foramen on the dentary. The second taxon is more advanced in that it has well-developed dentine tracts and its crown height is substantially greater than that of the root.

I have known of the presence of the two taxa since my earlier work on kangaroo rats (Zakrzewski, 1969, 1970) but withheld reporting them until more data could be obtained regarding the relationships of "*Etadonomys*." Recently, I reexamined pertinent materials from the Borchers l.f. and additional fossil and recent material bearing on the problem. The data obtained form the basis for this report.

## SYSTEMATIC PALEONTOLOGY

### *Prodipodomys* Hibbard, 1939

*Etadonomys* Hibbard, 1943; Trans. Kansas Acad. Sci. 46:185.

*Emended diagnosis*. Kangaroo rat in which crown height in adults is approximately the same as the root length. Evidence for two or more roots is

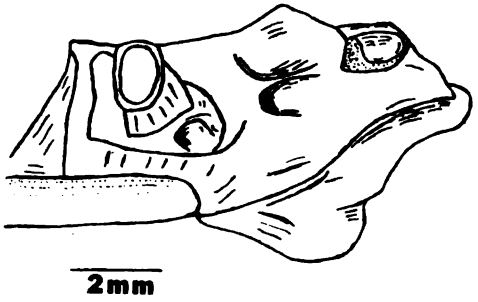


Fig. 1. Right dentary with $M_2$ of *Prodipodomys tiheni*.

easily observable on each of the teeth. Dentine tracts are absent or only slightly developed. A distinct anterocone is generally present on the $P^4$.

*Discussion*. "*Etadonomys*" was characterized as having a two-rooted $P_4$ and $M_1$, a single-rooted $M_2$ and $M_3$, a pit (temporal fossa) dorsal and labial to the mandibular foramen (Hibbard, 1943). Since the original description of *Etadonomys*, additional specimens have been obtained from the Borchers l.f. Among these specimens is a partial right dentary (UM 30009, Fig. 1). This specimen has the $M_3$ lingual to the mandibular foramen as it is in other *Prodipodomys* and *Dipodomys*. UM 30009 has a temporal fossa dorsal and labial to the mandibular foramen as in the holotype.

The relationship of foramen to fossa is variable in both *Prodipodomys* and *Dipodomys*. *P. griggsorum* lacks a fossa (Zakrzewski, 1970), whereas *P. centralis* has a slightly developed one (Hibbard, 1972). Among extant kangaroo rats some specimens also may lack a fossa and have only the foramen. Most specimens have the foramen in the fossa, a number have a small shelf that partially or fully covers the foramen, and a few have the fossa developed dorsal and labial to the foramen. In looking at the relationship between the fossa and foramen, I primarily examined specimens of *D. ordii* Woodhouse; however, the best example of the fossa dorsal and labial to the foramen was seen in a specimen of *D. elator* Merriam (MHP 8555). The variability seen in this character precludes its use as a taxonomic character at the generic level.

Evidence for at least two roots is generally discernible in *Prodipodomys*. $P_4$, $M_1$, and $M_2$ are generally two-rooted, although the latter may begin to show some fusion. $M_3$ may appear to be single-rooted, but close inspection shows evidence for the fusion of two roots, and an inflection of the root from the lingual to the labial side is always present. Among the upper teeth $P^4$, $M^1$, and $M^2$ are always three-rooted, although the latter may begin to show some fusion into two. In some $P^4$s four roots are observable. The $M^3$ may appear to be single-rooted, but close inspection shows evidence for at least two and in many cases three roots. I have not observed a simple

tubular root as is seen in $M^3$ of *Dipodomys*. In *Dipodomys* only the premolars show any evidence of having more than one root and in most cases they are not independent but show evidence of fusion.

Dentine tracts are absent or only slightly developed in *Prodipodomys* (Fig. 2A & D). They seldom exceed 0.7 mm in height. In contrast, tracts in *Dipodomys* are generally greater than 1.00 mm and seldom are less than 0.9 mm (Fig. 2B–C, E–F).

In *Prodipodomys* the cheek teeth retain evidence of their original bilophate nature longer during their life. This is especially true of the premolars. In the $P^4$ a distinct anterocone is generally discernible in *Prodipodomys* (Fig. 2A), whereas in *Dipodomys* the lophs fuse quickly and appear to be a single unit (Fig. 2B–C). This difference is not as discernible in the $P_4$ (Fig. 2D–F), as in both genera the quadrate or lophate nature of the tooth is retained longer in life. In fact, it is sometimes difficult to distinguish between $P_4$s of advanced *Prodipodomys* and primitive *Dipodomys*. Additional material may show that other characters exhibit some overlap at this level as well.

The relationship between *Prodipodomys* and *Dipodomys* remains questionable. Trends in the development of dental characteristics in *Prodipodomys* suggest that it was ancestral to *Dipodomys*. However, Voorhies (1975) when describing the genus *Eodipodomys* from the Clarendonian of Nebraska suggested that it was closely related to *Dipodomys*, whereas *Prodipodomys* represented a side branch in kangaroo rat evolution. *Eodipodomys* is based on a partial skeleton including a cranium with inflated auditory bullae and teeth with well-developed dentine tracts. The post-cranial material is similar to that of *Dipodomys* (Voorhies, 1975).

The problem with Voorhies' suggestion is the replacement of a precocious dipodomyine by a more primitive one in environments that should have been conducive to its continued existence. The primitive taxon then evolves toward a grade already reached by the precocious taxon. Perhaps *Eodipodomys* represents an early attempt by a parallel or convergent group to fill the niche presently occupied by *Dipodomys*. Among Clarendonian taxa the teeth of *Eodipodomys* most closely resemble those of *Lignimus hibbardi*, an entoptychine that Storer (1973) described from the WaKeeney l.f. of Kansas. Unfortunately, no associated post-cranial material of *Lignimus* or of *Prodipodomys* has been reported. It will be necessary to obtain additional skeletal material of all the taxa to see whether the dipodomyine characters of *Eodipodomys* reflect phylogenetic relationship or convergence.

*Prodipodomys tiheni* (Hibbard)

*Etadonomys tiheni* Hibbard, 1943; Trans. Kansas Acad. Sci., 46:185.

*Emended diagnosis. Prodipodomys tiheni* is distinguished from other species in the genus by being more hypsodont, having slightly higher dentine tracts, and a somewhat deeper masseteric fossa.

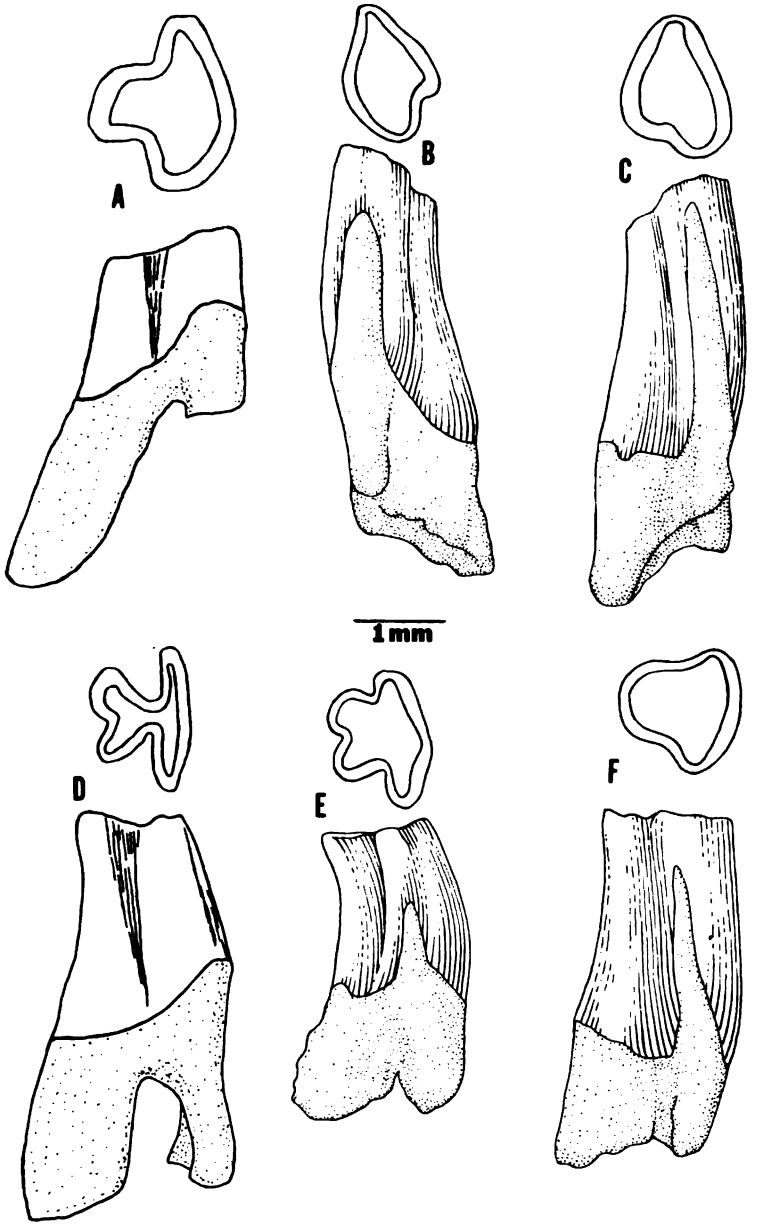


Fig. 2. Premolars of *Prodipodomys* and *Dipodomys*. A & D; *P. tiheni*; A, UM 72615, $RP^4$; D, UM 72617, $RP_4$; occlusal and side views. B & E; *D. hibbardi*; B, *Holotype* UM 72614, $RP^4$; E, UM 72616, $LP_4$; occlusal and side views. C & F; *D. compactus*, USNM 43304, C, $LP^4$; F, $LP_4$; occlusal and side views.

*Discussion. P. tiheni* represents the most hypsodont member of a chronocline for species of *Prodipodomys* in Kansas (Table 1). This cline begins with *P. kansensis* in the Edson Quarry l.f. (Hemphillian) and continues through *P. griggsorum* (Saw Rock Canyon l.f.—Hemphillian), *P. centralis* (Rexroad l.f.—Blancan) and *P. tiheni*. It is not known whether this cline represents a phylogenetic lineage as well, but neither morphology or stratigraphy, as presently understood, would negate such a relationship. Increase in the size of dentine tracts follows the same cline.

### *Dipodomys* Gray

*Emended diagnosis.* Kangaroo rat in which crown height in adults generally exceeds the length of the root. The molars are single-rooted in advanced species. The root is generally a tubular continuum of the crown. Primitive species may possess molars with more than one root but they are generally fused rather than independent. The $P_4$ is two-rooted and $P^4$ three-rooted in primitive species. In advanced species the premolars become single-rooted, through fusion. Dentine tracts are well-developed. The anterocone on $P^4$ is lost early with wear.

*Discussion. Dipodomys* was originally characterized, in part, as having evergrowing cheek teeth. Hibbard (1953) emended the diagnosis by stating that the premolars were rooted in the adult and/or old adult stage. Subsequently, Hibbard (1954), pointed out that some primitive species of extant kangaroo rats, *D. sennetti* (J. A. Allen) and *D. compactus* True, also have rooted molars late in their life.

Nader (1966) took issue with Hibbard's diagnosis, in part because the latter often used rootless as a synonym for evergrowing. As Nader correctly pointed out, no tooth is rootless and he proposed the terms opaeodont (open tooth) for evergrowing teeth and kleistodont (closed tooth) for teeth with distinct roots to avoid confusion. Other workers (Phillips & Oxberry, 1972) when discussing evergrowing teeth have used the term "anatomical root" when referring to evergrowing molars.

Nader (1966) pointed out that other extant species of *Dipodomys* have roots that eventually close over during the life of the individual and divided the genus into opaeodont and kleistodont groups. My observations suggest that all species of *Dipodomys* have closed roots at some post-adult stage of life. The exact stage at which closure occurs varies among species and most likely among individuals in any particular species. It became apparent from a study of 25 *D. ordii* that $M_3^3$s are the last teeth to have their roots close over. I then looked at $M_3^3$s of other species that were in old age. In most instances once I found a $M_3^3$ with a closed root I did not examine any more specimens from that taxon. If maintenance of an open root represents an advanced character, then *D. compactus* is the most primitive of extant species and *D. agilis* Gambel is the most advanced.

Table 1. Measurements of premolars in *Prodipodomys* and *Dipodomys hibbardi*.

| Character | N | GL | | | GW | | | GH | | | DTH | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $P^4$ | | $\bar{x}$ | $2S_{\bar{x}}$ | OR | $\bar{x}$ | $2S_{\bar{x}}$ | OR | $\bar{x}$ | $2S_{\bar{x}}$ | OR | $\bar{x}$ | $2S_{\bar{x}}$ | OR |
| *P. centralis* | 6 | 1.26 | 0.012 | 1.10–1.48 | 1.55 | 0.012 | 1.31–1.76 | 1.47 | 0.026 | 0.94–1.77 | 0.28 | 0.018 | 0.00–0.55 |
| *P. tiheni* | 5 | 1.22 | 0.002 | 1.08–1.32 | 1.47 | 0.012 | 1.34–1.65 | 1.89 | 0.024 | 1.45–2.21 | 0.55 | 0.002 | 0.44–0.72 |
| *D. hibbardi* | 3 | 1.20 | 0.070 | 1.14–1.26 | 1.64 | 0.012 | 1.50–1.72 | 2.25 | 0.188 | 1.80–2.77 | 1.59 | 0.200 | 1.43–1.80 |
| $P_4$ | | | | | | | | | | | | | |
| *P. centralis* | 7 | 1.14 | 0.004 | 1.05–1.25 | 1.28 | 0.012 | 1.19–1.35 | 1.54 | 0.008 | 1.32–1.75 | 0.06 | 0.0008 | 0.00–0.33 |
| *P. tiheni* | 5 | 1.15 | 0.0008 | 1.11–1.19 | 1.38 | 0.012 | 1.13–1.45 | 1.90 | 0.006 | 1.76–2.01 | 0.45 | 0.006 | 0.38–0.53 |
| *D. hibbardi* | 4 | 1.14 | 0.020 | 1.04–1.20 | 1.36 | 0.170 | 1.15–1.54 | 1.79 | 0.160 | 1.60–2.00 | 0.81 | 0.310 | 0.35–1.03 |

N = Number of specimens, GL = Greatest length, GW = Greatest width, GH = Greatest height, DTH = Dentine tract height, $\bar{x}$ = mean, $2S_{\bar{x}}$ = 2 Standard errors of mean, OR = Observed range.

Related to the reduction of the roots is an increase in dentine tract height. *Dipodomys* generally has a tract height of 1.00 mm or more. A similar increase in tract height coeval with reduction of roots is seen in most microtine rodents. Workers (Phillips and Oxberry, 1972; van der Meulen, 1973) have shown that in microtines the dentine tract is covered by a thin layer of cementum that apparently is observable only after using stains applied to study the histology of the specimens. Sharpey's fibers, which help to hold the teeth in the jaw, attach to this cement. The dentine tracts are in a sense reversed roots (Mahn, 1890). Although I know of no study where the teeth of *Dipodomys* have been subjected to a similar histologic analysis, similar results should be obtained because of the analogous changes that have taken place during root reduction. These results could also be obtained in extant Geomyidae as they, too, have evolved from forms with distinct roots to those with evergrowing teeth.

In *Dipodomys* the distinctiveness of the anterocone on the $P^4$ is lost quickly in life. Although there might be a slight inflection of the enamel between the original lophs it is generally only on one side of the tooth and never as deep as in *Prodipodomys* (Fig. 2A–C).

*Dipodomys hibbardi* sp. nov.

*Holotype*. UM 72614, $RP^4$.

*Horizon* and *locality*. Late Pliocene, Crooked Creek fm., Borchers l.f. NW¼, Sec. 21, T.33S., R23W., Meade Co., Kansas.

*Paratypes*. UM 72616, $LP_4$; UM 54811, 4 additional isolated teeth; UM 54812, 8 isolated teeth.

*Diagnosis*. Kangaroo rat near the size of *Dipodomys compactus* but distinguished from that taxon by its shorter dentine tracts and better developed roots.

*Description of holotype*. The holotype (UM 72614) is a $RP^4$ (Fig. 2B). It has a length of 1.19 mm, width of 1.69 mm, crown height of 2.77 mm, and a dentine tract height of 1.43 mm. The tooth is not divided into two distinct lophs as only a slight inflection occurs in the enamel crown on the labial side (Fig. 2B) as in *D. compactus* (Fig. 2C). The tooth is 3-rooted but fusion has begun and the roots are not as robust as they are in *Prodipodomys*.

*Discussion*. *Dipodomys hibbardi* is approximately intermediate between *Prodipodomys* and *D. compactus* in its state of evolutionary development. The dentine tracts are shorter than they are in the latter but higher than they are in the former. Root development also is in an intermediate stage (Fig. 2A–C).

$P_4$ appears to be the most primitive tooth. It has an occlusal pattern more like *Prodipodomys* (Fig. 2A–B) but in some instances the roots are less developed than in *D. compactus* (Fig. 2B–C).

*Etymology*. The species is named for the late Claude W. Hibbard in recognition of his work on late Cenozoic paleomammalogy.

## Age of the Borchers Local Fauna

Schultz and Martin (1977) consider the Borchers l.f. among the oldest of the post-Blancan local faunas along with the Curtis Ranch l.f. of Arizona. Their rationale for the placement of the Borchers in the Irvingtonian is the absence of many Blancan "index" genera in the Borchers and the faunal similarity of the Borchers with the Sappa l.f. of Nebraska. The Sappa underlies the Type S Pearlette Ash, which has been dated at 1.2 m.y., whereas the Borchers overlies the Type B Pearlette Ash dated at 1.9 m.y. (Boellstorf, 1976).

Lindsay et al. (1975) place the Curtis Ranch l.f. in the Irvingtonian land-mammal age because of the joint occurrence of the genera *Lepus* and *Dipodomys*. They place the Borchers in the Blancan based on their interpretation of paleomagnetic and radiometric evidence, which suggests that the Borchers is located in the lower part of the reversely magnetized Matuyama epoch.

In 1975 I suggested, on stratigraphic and faunal grounds, that the Borchers should be placed in the Blancan land-mammal age (Zakrzewski, 1975). The addition of *Dipodomys* to the Borchers l.f. along with the previously reported *Lepus* (Hibbard, 1941), together with Schultz and Martin's arguments, suggests that I may have misassigned the local fauna in its stratigraphic context. However, other data suggests that my 1975 assignment is correct.

The absence of many Blancan "index" genera in the Borchers l.f. could be ascribed to the fact that many of the Blancan "index" genera are large mammals, whereas the Borchers is basically a small mammal fauna. Hibbard (1941) suggested on the basis of the animals and their preserved elements that the fossils accumulated as the result of predation by owls. This selection bias would limit the size of organism in the deposit.

It is true that the Borchers lacks Fejfar's Type I microtines (Schultz and Martin, 1977). However, Schultz and Martin point out that *Ondatra idahoensis* and *Synaptomys* (*Metaxyomys*) (Fejfar's Type II microtines) are present. Both of these taxa are in the Grand View l.f. of Idaho, which they and others (including myself) consider to be Blancan. The only additional microtine in the Grand View is *Ophiomys*. It has been suggested (Zakrzewski, 1969) that *Ophiomys* was an upland dweller. The majority of taxa in Borchers are suggestive of an upland environment. The absence of *Ophiomys* in the Borchers could be accounted for by the presence of *Sigmodon*. It has been demonstrated (Baker, 1969) that *Sigmodon* replaces microtines

in areas where the two are in competition. *Sigmodon* is not known from the Grand View probably because of biogeographical and climatic constraints.

Numerous taxa in the Borchers are suggestive of a Blancan age. *Prodipodomys, Hypolagus,* and *Nekrolagus* are considered to be "index" genera for the Blancan. The only other fauna from which *Sorex taylori* and *Perognathus gidleyi* have been reported is the Rexroad, which is considered a typical Blancan fauna. In addition, Eshelman (1975) reports four species of cricetine found in the Borchers—*Reithrodontomys pratnicola, Onychomys fossilis, Sigmodon minor,* and *Neotoma taylori*—that also occur in the White Rock l.f. (Blancan of Kansas). The last taxon is a hodomyine-like woodrat (S-shaped $M_3$). Woodrats with hodomyine-like $M_3$s are fairly common in Blancan faunas, whereas woodrats with neotomine $M_3$s (bilophate) are not found in the fossil record of North America until Irvingtonian time.

The only published account of the fauna from the type locality of the Sappa formation is by Schultz and Martin in 1970 (Schultz and Martin, 1977). When the faunal lists of the Sappa and Borchers are compared, a high correlation is seen at the generic level. However, the three taxa in the Sappa that have been identified to species are not found in the Borchers.

We are left with co-occurrence of *Lepus* and *Dipodomys,* two Irvingtonian "index" genera that need to be explained away. Although we cannot ignore the presence of these taxa, it should be kept in mind that both are rare elements in the Borchers and that at least the *Dipodomys* is at a very primitive stage of evolution. The concept of land mammal ages has served biostratigraphy well. However, as more faunas are found we are sure to find more overlaps among the taxa near the age boundaries. Likewise, as more radiometric dates and paleomagnetic analyses are obtained and applied to faunal sequences we will find more evidence of homotaxis or migrational lag time. It will become philosophically, if not psychologically, uncomfortable to assign a fauna to a land mammal age on the sole basis of first appearance when the physical evidence demonstrates there is a significant, though perhaps slight, difference in the radiometric date, or the paleomagnetic evidence demonstrates a difference in the magnetic field. A time boundary should be instantaneous.

The Irvingtonian land-mammal age was originally defined, in part, by the first appearance of the genus *Mammuthus* (Savage, 1951). Although the definition of the age has been expanded since that time, biostratigraphers feel most secure in assigning a fauna to the Irvingtonian age when *Mammuthus* is present. Madden (1980) has shown that the earliest occurrence of *Mammuthus* in North America is approximately 1.5 m.y.a. *Mammuthus* has been found (Izett, pers. comm.) in sediments that stratigraphically overlie the Borchers l.f. (Kovach, 1979). The *Mammuthus* material is associated with an ash that has been dated at 1.2 m.y.a. by Boellstorf (1976), but which Izett (pers. comm.) thinks is about 1.4 m.y.a. on the basis of

mineralogy. Either date conforms to previously obtained radiometrically-dated occurrences of *Mammuthus*.

In addition, two sites of the Nash l.f. have been obtained from sediments that are stratigraphically between the Borchers and the ash (Kovach, 1979). *Synaptomys* (*Mictomys*) was reported from the Nash (Zakrzewski, 1975) and its presence has been confirmed by Eshelman (pers. comm.). The subgenus *Mictomys* has not been reported from Blancan faunas. The subgenus *Metaxomys* is known from both the Borchers and Grand View.

Eshelman (pers. comm.) also reports *Allophaiomys* from the Nash. The presence of the taxon suggests that, if there is a fauna in Meade County that is correlative with the type Sappa, it may be the Nash and not the Borchers. The physical and biostratigraphic data presented above is strong evidence for maintaining the Borchers l.f. in the Blancan land-mammal age.

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## Literature Cited

Baker, R. H. 1969. Cotton rats of the *Sigmodon fulviventer* group. Misc. Publ., Mus. Nat. Hist., Univ. Kansas 51:177–232.

Boellstorf, J. 1976. The succession of late Cenozoic volcanic ashes in the Great Plains: A progress report. Kansas Geol. Surv. Guidebook Ser. 1:37–71.

Eshelman, R. E. 1975. Geology and paleontology of the early Pleistocene (late Blancan) White Rock fauna from north-central Kansas. Univ. Michigan, Papers Paleont., 13 (C. W. Hibbard Mem. Vol. 4), 60 pp.

Hibbard, C. W. 1941. The Borchers fauna, a new Pleistocene interglacial fauna from Meade County, Kansas. Bull. Kansas Geol. Surv. 38:197–220.

Hibbard, C. W. 1943. *Etadonomys*, a new Pleistocene heteromyid rodent, and notes on other Kansas mammals. Trans. Kansas Acad. Sci. 46:185–191.

Hibbard, C. W. 1953. A change in the definition of the generic characters of the genus *Dipodomys* Gray. J. Mamm. 34:264–265.

Hibbard, C. W. 1954. Second contribution to the Rexroad fauna. Trans. Kansas Acad. Sci. 57:221–237.

Hibbard, C. W. 1972. Class Mammalia. Pp. 77–116, *in* Early Pleistocene pre-glacial and glacial rocks and faunas of north-central Nebraska (M. F. Skinner and C. W. Hibbard, eds.) Bull. Amer. Mus. Nat. Hist. 148:1–148.

Kovach, J. T. 1979. Geology of late Cenozoic sediments of the Borchers' Badlands, Meade County, Kansas. Unpubl. MS. thesis, Fort Hays State Univ. 129 pp.

Lindsay, E. H., N. M. Johnson, and N. D. Opdyke. 1975. Preliminary correlation of North American land mammal ages and geomagnetic chronology. Pp. 111–119, *in* Studies on Cenozoic paleontology and stratigraphy (G. R. Smith and N. E. Friedland, eds.) Univ. Michigan Papers Paleont., 12 (C. W. Hibbard Mem. Vol. 3), 143 pp.

Madden, C. T. 1980. Earliest isotopically dated *Mammuthus* from North America. Quaternary Res. 13:147–150.

Mahn, R. 1890. Bau un Entwicklung der Molaren bei *Mus* und *Arvicola*. Morph. Jahr. 16:652–685.

van der Meulen, A. J. 1973. Middle Pleistocene smaller mammals from Monte Peglia, (Orvieto, Italy) with special reference to the phylogeny of *Microtus* (Arvicolidae, Rodentia). Quaternaria 17:1–144.

Nader, I. A. 1966. Roots of teeth as a generic character in the kangaroo rats, *Dipodomys*. Bull. Biol. Res. Cent. Iraq 2:62–69.

Phillips, C. J., and B. Oxberry. 1972. Comparative histology of molar dentitions of *Microtus* and *Clethrionomys*, with comments on dental evolution in microtine rodents. J. Mamm. 53:1–20.

Savage, D. E. 1951. Late Cenozoic vertebrates of the San Francisco Bay region. Bull. Dept. Geol. Sci., Univ. California 28:215–314.

Schultz, C. B., and L. D. Martin. 1977. Biostratigraphy of the Neogene–Quaternary boundary in North America. Gior. Geol., Bologna 26:285–295.

Storer, J. E. 1973. The entoptychine geomyid *Lignimus* (Mammalia: Rodentia) from Kansas and Nebraska. Canadian J. Earth Sci. 10:72–83.

Voorhies, M. R. 1975. A new genus and species of fossil kangaroo rat and its burrow. J. Mamm. 56:160–176.

Zakrzewski, R. J. 1969. The rodents from the Hagerman local fauna, upper Pliocene of Idaho. Contrib. Mus. Paleont. Univ. Michigan 23:1–33.

Zakrzewski, R. J. 1970. Notes on kangaroo rats from the Pliocene of southwestern Kansas, with the description of a new species. J. Paleont. 44:474–477.

Zakrzewski, R. J. 1975. Pleistocene stratigraphy and paleontology in western Kansas: the state of the art, 1974. Pp. 121–128, *in* Studies on Cenozoic paleontology and stratigraphy (G. R. Smith, and N. E. Friedland, eds.) Univ. Michigan Papers Paleont., 12 (C. W. Hibbard Mem. Vol. 3), 143 p.

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# An Annotated List of the Leafhoppers (Homoptera: Cicadellidae) from Tallgrass Prairie of Kansas and Oklahoma[1]

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ABSTRACT

More than 110 species of leafhoppers representing 54 genera in 12 subfamilies are reported from the Tallgrass Prairie found in the Flint Hills area of Kansas and extending into the Osage Hills of Oklahoma. Thirteen species are considered major inhabitors of the Tallgrass Prairie. Three species were taken from areas with tall prairie grasses but not considered true prairie.

The first attempt to list the Kansas leafhoppers was by Popenoe (1885). Crevecoeur (1905) listed 80 species and varieties from Onaga, Kansas. The first comprehensive list was compiled by Lawson (1920) who identified 211 Kansas species taken mostly from eastern and western counties of the state. More recently Blocker et al. (1972) compiled a list of leafhoppers found on shortgrass prairie in western Kansas.

This study lists the species of leafhoppers collected on tallgrass prairie in the Flint Hills of Kansas and Oklahoma, by combining unpublished research, a published report, and new collection records.

The Flint Hills of eastern Kansas extend from near the Nebraska-Kansas border, south into northern Oklahoma where they blend into the Osage Hills. West of the Flint Hills is a gradual transition into mixed prairie (Anderson, 1953).

The area is essentially bluestem prairie with minor grasses and forbs. The major grass species are *Andropogon scaparius* Michx. (little bluestem), *A. gerardi* (Vitman) (big bluestem), *Bouteloua curtipencula* (Michx.) Torr. (side-oats grama), *Poa pratensis* L. (Kentucky bluegrass), *Sorghastrum nutans* (L.) Nash (indiangrass), and *Panicum virgatum* L. (switchgrass).

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Forbs are present but are not a major percentage of climax species (Anderson and Fly, 1955).

## Materials and Methods

The species identified are from the following collections:

H. D. Blocker and R. Reed (1972): Lists 52 species from Osage County, Oklahoma, representing the southern range of the Flint Hills at its junction with the Osage Hills.

C. E. Mason (1973): Lists 58 species collected from Donaldson Research Pastures, Riley Co. Kansas, and an unburned-ungrazed pasture 6 km northwest of Manhattan, Kansas. Both sites are true Tallgrass Prairie.

D. H. Johnson: Collected at Donaldson Pastures from 1958 through 1960.

R. L. Baldridge (1969): Lists 38 leafhoppers with their parasites in 55 Kansas counties. Five of the counties are in the Flint Hills.

P. B. Lawson (1920): Lists 211 species throughout Kansas, with many designated as grass feeders.

S. Frary Smith: Swept pure prairie and somewhat grassy areas in the following Kansas counties—Butler, Chase, Cowley, Geary (Konza Prairie), Marshall, Morris, and Riley in 1978.

P. S. Cwikla: Collected from pure stands of prairie grasses at the U.S.D.A.'s Plant Materials Center, Riley Co. Kansas, during the summer of 1978.

Identification of leafhoppers from Smith and Cwikla materials were made by the senior author. Specific host plant records were obtained by sweeping various pure stands of tall prairie grasses at the U.S.D.A.'s Plant Materials Center: big and little bluestem, and bluestem (*Andropogon halli* Hack.), switchgrass, indiangrass, sideoats grama, sand lovegrass (*Eragrostis trichodes* (Nutt., Wood)), and prairie cordgrass (*Spartina pectinata* Link). All leafhoppers from the Smith and Cwikla collections are deposited in the Kansas State Entomology Museum.

The senior author estimated abundance based on personal collecting and representation in the Kansas State Entomology Research Collection. When the insect was extremely plentiful and collected at most sites, it was designated abundant. When collected frequently at most of the collection sites, it was designated common; when collected in low numbers, uncommon. If only one or two specimens were collected, the insect was designated rare. Species and genera are listed alphabetically under subfamily. Collecting dates are given, when known, along with counties where the insect has been collected.

## Discussion

More than 110 species (specimens of some genera were not identified to species) representing 54 genera in 12 subfamilies were reported. Of the 110

species listed, 13 are major inhabitors of the Flint Hills: *Draeculacephala mollipes* (Say), *Graphocephala hieroglyphica* (Say), *Aceratagallia uhleri* (Van Duzee), *Empoasca* sp., *Athysanella texana* (Osborn), *Balclutha neglecta* (DeLong and Davidson), *Chlorotettix spatulatus* Osborn and Ball, *Endria inimica* (Say), *Exitianus exitiosus* (Uhler), *Flexamia prairiana* DeLong, *Graminella mohri* DeLong, *Macrosteles fascifrons* (Stal), and *Stirellus bicolor* (Van Duzee).

*Graphocephala coccinea* (Forster), *Athysanella balli* (Osborn), and *Norvellina helenae* Ball were taken in areas not considered true prairie, but containing tall prairie grasses.

Collection localities from the extensively collected sites of Osage Co. OK and Riley Co. KS, show that the northern range of *Gyponana angula* DeLong and *Balclutha hebe* (Kirkaldy) ends at the southern tip of the Flint Hills. *Xestocephalus brunneus* Van Duzee, *Amblysellus valens* (Beamer and Tuthill), *Flexamia curvata* DeLong, *F. decora* Beamer and Tuthill, and *Texananus decorus* (Osborn and Ball) are found only in the northern half of the Kansas Flint Hills.

Subfamily LEDRINAE.
- Genus *Xerophloea* Germar.
  - *majesta* Lawson. Uncommon. Osage Co. OK, Riley Co. KS: July–September.
  - *major* Baker. Rare. Riley Co. KS.
  - *peltata* (Uhler). Common. Butler, Riley Co. KS, Osage Co. OK: June–September, sweeping *Cassia fasculata*.

Subfamily DORYCEPHALINAE.
- Genus *Dorycephalus* Kouchakewitch.
  - *platyrhynchus* Osborn. Rare. Riley Co. KS: May–June, Oman (1949) reported feeding only on species of *Elymus*, wild rye.

Subfamily HECALINAE.
- Genus *Hecalus* Stal.
  - *lineatus* (Uhler). Rare. Riley Co. KS: August, sweeping prairie cordgrass.
- Genus *Parabolocratus* Fieber.
  - *curtus* Shaw. Uncommon. Osage Co. OK: May–September.
  - *flavidus* Signoret. Uncommon. Riley Co. KS, Osage Co. OK: August.
  - *grandis* Shaw. Common. Chase, Geary, Riley Co. KS, Osage Co. OK: April–August.
  - *viridis* (Uhler). Common. Butler, Chase, Geary, Marshall, Riley Co. KS: July–August.

Subfamily AGALLIINAE.
- Genus *Aceratagallia* Kirkaldy.
  - *calcaris* Oman. Rare. Osage Co. OK: May.

*humilis* Oman. Common. Butler, Marshall, Riley Co. KS: June–August, sweeping purple prairie clover and *Cassia fasculata*.
*sanguinolenta* (Provancher). Uncommon. Riley Co. KS: April–November.
*uhleri* (Van Duzee). Abundant. Butler, Chase, Cowley, Geary, Riley Co. KS, Osage Co. OK: May–October.
*vulgaris* Oman. Common. Butler, Cowley, Marshall, Riley Co. KS, Osage Co. OK: June–August.
Genus *Agallia* Curtis.
*constricta* Van Duzee. Rare. Osage Co. OK: September.
Subfamily IDIOCERINAE.
Genus *Idiocerus* Lewis.
*nervatus* Van Duzee. Rare. Osage Co. OK: September.
Subfamily GYPONINAE.
Genus *Gypona* Germar.
*melanota* Spangberg. Uncommon. Pottawatomie, Riley Co. KS.
Genus *Gyponana* Ball.
*angula* DeLong, Uncommon. Osage Co. OK: June.
*vincula* DeLong. Uncommon. Riley Co. KS: June.
Genus *Ponana* (Ponana) Ball.
*puncticollis* (Spangberg). Uncommon. Pottawatomie, Riley Co. KS.
Genus *Prairiana* Ball.
*kansana* Ball. Rare. Riley Co. KS.
*cinerea* (Uhler). Uncommon. Riley Co. KS: May.
*subta* Ball. Uncommon. Riley Co. KS: May.
Subfamily IASSINAE.
Genus *Penestragania* Beamer and Lawson.
*robusta* (Uhler). Rare. Osage Co. OK: September.
Subfamily XESTOCEPHALINAE.
Genus *Xestocephalus* Van Duzee.
*brunneus* Van Duzee. Rare. Riley Co. KS.
*pulicarius* Van Duzee. Common when collected by a D-vac vacuum collector from near soil surface or crown area of plant; rarely collected sweeping. Osage Co. OK, Riley Co. KS: June–November.
Subfamily NEOCOELIDIINAE.
Genus *Neocoelidia* Gillette and Baker.
*bifida* DeLong. Uncommon. Cowley, Riley Co. KS: July–August.
Subfamily CICADELLINAE.
Genus *Ciminius* Metcalf and Bruner.
*harti* (Ball). Common. Chase, Cowley, Butler, Marshall, Morris, Riley Co. KS: June–August, bluestem pastures.
Genus *Draeculacephala* Ball.
*mollipes* (Say). Abundant. Cowley, Geary, Morris, Riley Co. KS, Os-

age Co. OK: May–September, sweeping little bluestem, sand lovegrass, big bluestem, eastern gamma grass, sideoats grama, prairie cordgrass, common reed, and switchgrass.

Genus *Graphocephala* Van Duzee.

*hieroglyphica* (Say). Common. Butler, Chase, Geary, Morris, Riley Co. KS: June–August, sweeping little bluestem and *Cassia fasculata*.

*coccinea* (Föster). Rare. Morris Co. KS: June, although grassy not true prairie.

Genus *Tylozygus* Fieber.

*bifida* (Say). Uncommon. Pottawatomie, Riley Co. KS: June–September.

Subfamily TYPHLOCYBINAE.

Genus *Alconeura* Ball and DeLong.

species. Riley Co. KS.

Genus *Dicranoneura* Douglas.

species. Osage Co. KS.

Genus *Dikraneura* Hardy.

species. Riley Co. KS.

Genus *Empoasca* Walsh.

species. Butler, Geary, Riley Co. KS, Osage Co. OK: June–July, contains species which are abundant.

Genus *Erythroneura* Fitch.

*comes* (Say). Pottawatomie, Riley Co. KS: May–October.

species. Butler, Cowley, Marshall, Riley Co. KS, Osage Co. OK: June–August.

Genus *Forcipata* DeLong and Caldwell.

species. Riley Co. KS.

Subfamily DELTOCEPHALINAE.

Genus *Amblysellus* Sleesman.

*curtisi* (Fitch). Uncommon. Riley Co. KS.

*punctatus* (Osborn and Ball). Rare. Riley Co. KS.

*valens* (Beamer and Tuthill). Rare. Riley Co. KS: October.

Genus *Athysanella* (*Amphipyga*) Osborn.

*attenuata* Baker. Uncommon. Marshall Co. KS: July–August.

*balli* (Osborn). Uncommon. Marshall, Morris Co. KS: June–August.

*texana* (Osborn). Common. Butler, Chase, Cowley, Morris, Riley Co. KS, Osage Co. OK: May–September.

Genus *Athysanella* (*Athysanella*) Baker.

*incongrua* Baker. Uncommon. Chase, Cowley, Riley Co. KS: July.

*supina* Ball and Beamer. Rare. Riley Co. KS.

Genus *Athysanella* (*Gladionura*) Osborn.

*argenteola* (Uhler). Rare. Marshall Co. KS: July.

*emarginata* Osborn. Uncommon. Marshall Co. KS, Osage Co. OK: July.

Genus *Balclutha* Kirkaldy.

*diluta* Blocker. Rare. Osage Co. OK: September.

*guajanae* (DeLong). Rare. Riley Co. KS: August, sweeping big bluestem.

*hebe* (Kirkaldy). Rare. Osage Co. OK: September.

*incisa* (Matsumura). Rare. Osage Co. OK, Riley Co. KS: October, sweeping switchgrass.

*neglecta* (DeLong and Davidson). Abundant. Butler, Chase, Cowley, Geary, Marshall, Morris, Riley Co. KS, Osage Co. OK: May–September, sweeping lovegrass and sideoats grama.

Genus *Chlorotettix* Van Duzee.

*spatulatus* Osborn and Ball. Common. Butler, Chase, Cowley, Marshall, Morris, Riley Co. KS, Osage Co. OK: June–September.

*viridius* Van Duzee. Rare. Riley Co. KS.

*stolatus* Ball. Rare. Riley Co. KS.

*tunicatus* Ball. Rare. Riley Co. KS.

Genus *Commellus* Osborn and Ball.

*comma* (Van Duzee). Uncommon. Chase, Cowley, Geary, Riley Co. KS, Osage Co. OK: June–July.

Genus *Deltocephalus* Burmeister.

*balli* Van Duzee. Rare. Riley Co. KS.

*caperatus* (Ball). Rare. Riley Co. KS.

Genus *Driotura* Osborn and Ball.

*gammaroides* (Van Duzee). Uncommon. Morris, Riley Co. KS: June–August.

*robusta* (Osborn and Ball). Common. Butler, Chase, Geary, Marshall, Morris, Riley Co. KS: July–August.

Genus *Endria* Oman.

*inimica* (Say). Abundant. Butler, Chase, Cowley, Geary, Morris, Riley Co. KS, Osage Co. OK: June–September, sweeping switchgrass, sideoats grama, lovegrass, and common reed.

Genus *Exitianus* Ball.

*exitiosus* (Uhler). Abundant. Butler, Chase, Cowley, Geary, Marshall, Morris, Riley Co. KS, Osage Co. OK: May–September, sweeping little bluestem, sideoats grama, indiangrass, cordgrass, prairie clover, and common reed.

Genus *Extrusanus* Oman.

*extrusus* (Van Duzee). Rare. Riley Co. KS: May–June.

*ovatus* (Sanders and DeLong). Uncommon. Riley Co. KS, Osage Co. OK: May.

Genus *Flexamia* DeLong.

*abbreviata* (Osborn and Ball). Uncommon. Chase, Riley Co. KS: June–July.

*albida* (Osborn and Ball). Rare. Riley Co. KS: July–August.

*areolata* (Ball). Rare. Riley Co. KS: Osage Co. OK: September.

*atlantica* (DeLong). Uncommon. Riley Co. KS, Osage Co. OK: June–August.

*curvata* DeLong. Uncommon. Butler, Chase, Morris, Riley Co. KS: June–October.

*decora* Beamer and Tuthill. Rare. Riley Co. KS.

*graminea* (Ball). Uncommon. Riley Co. KS, Osage Co. OK: August–September.

*inflata* (Osborn and Ball). Uncommon. Cowley, Riley Co. KS, Osage Co. OK: June–September.

*pectinata* (Osborn and Ball). Uncommon. Riley Co. KS: May–October.

*picta* (Osborn and Ball). Uncommon. Butler, Riley Co. KS, Osage Co. OK: June–September.

*prairiana* DeLong. Common. Chase, Riley Co. KS, Osage Co. OK: June–October.

*reflexa* (Osborn and Ball). Uncommon. Riley Co. KS, Osage Co. OK: May–September.

Genus *Gillettiella* Osborn.

*atropuncta* (Gillette). Uncommon. Riley Co. KS, Osage Co. OK: May–October.

Genus *Graminella* DeLong.

*mohri* DeLong. Abundant. Butler, Chase, Cowley, Geary, Marshall, Morris, Riley Co. KS, Osage Co., OK: May–October.

*nigrifrons* (Forbes). Uncommon. Osage Co. OK: July–September.

*sonora* (Ball). Uncommon. Riley Co. KS, Osage Co. OK: June–September.

Genus *Kansendria* Kramer.

*kansiensis* (Tuthill). Uncommon. Riley Co. KS, Osage Co. OK: June–August.

Genus *Laevicephalus* DeLong.

*minimus* (Osborn and Ball). Uncommon. Cowley, Riley Co. KS: July–August.

*parvulus* (Gillette). Uncommon. Butler, Riley Co. KS: July.

*unicoloratus* (Gillette and Baker). Common. Chase, Cowley, Morris, Riley Co. KS, Osage Co. OK: May–November.

Genus *Limotettix* Sahlberg.

*parallelus* (Van Duzee). Rare. Riley Co. KS: June.

*striolus* (Fallen). Uncommon. Pottawatomie, Riley Co. KS: June–August.

Genus *Lonatura* Osborn and Ball.
*catalina* Osborn and Ball. Rare. Butler, Marshall Co. KS: July.
Genus *Macrosteles* Fieber.
*fascifrons* (Stal). Abundant. Butler, Chase, Geary, Morris, Riley Co. KS, Osage Co. OK: May–October.
Genus *Mesamia* Ball.
*coloradensis* (Gillette and Baker). Uncommon. Geary, Marshall, Riley Co. KS, Osage Co. OK: May–October.
*nigridorsum* (Ball). Uncommon. Morris, Riley Co. KS: July.
Genus *Mocuellus* Ribaut.
*caprillus* Ross and Hamilton. Uncommon. Chase, Marshall Co. KS: July.
Genus *Norvellina* Ball.
*seminuda* (Say). Uncommon. Butler, Marshall, Morris, Riley Co. KS, Osage Co. OK: July–September.
*helenae* Ball. Rare. Butler Co. KS: July, although grassy not true prairie.
Genus *Ophiola* Edwards.
*anthracinus* Van Duzee. Rare. Riley Co. KS.
*uhleri* (Ball). Rare. Riley Co. KS.
Genus *Paraphlepsius* Baker.
*altus* (Osborn and Ball). Common. Butler, Chase, Marshall, Morris, Riley Co. KS: July–September.
*blockeri* Cwikla. Uncommon. Butler, Cowley, Marshall, Riley Co. KS: July–August.
*irroratus* (Say). Uncommon. Butler, Cowley, Riley Co. KS, Osage Co. OK: July–September.
*lobatus* (Osborn). Uncommon. Riley Co. KS, Osage Co. OK: July–October.
*solidaginis* (Walker). Uncommon. Chase, Riley Co. KS, Osage Co. OK: July–October.
*truncatus* (Van Duzee). Rare. Riley Co. KS: July.
Genus *Pendarus* Ball.
*punctiscriptus* (Van Duzee). Rare. Riley Co. KS: June–September.
Genus *Planicephalus* Linnavuori.
*flavocostatus* (Van Duzee). Rare. Geary Co. KS: June.
Genus *Polyamia* DeLong.
*caperata* (Ball). Uncommon. Osage Co. OK: June–September.
species. Cowley, Riley Co. KS: July–September.
Genus *Psammotettix* Haupt.
*lividellus* (Zetterstedt). Rare. Butler, Cowley Co. KS: June–July.
Genus *Scaphytopius* Ball.
*acutus* (Say). Uncommon. Riley Co. KS: June–October.

*cinereus* (Osborn and Ball). Common. Chase, Marshall, Morris, Riley Co. KS, Osage Co. OK: May–September.
*frontalis* (Van Duzee). Uncommon. Riley Co. KS: July–October.
*fuscicephalus* Hepner. Rare. Osage Co. OK: September.
Genus *Stirellus* Osborn and Ball.
*bicolor* (Van Duzee). Common. Butler, Chase, Cowley, Marshall, Riley Co. KS, Osage Co. OK: July–September.
*obtutus* (Van Duzee). Rare. Riley Co. KS.
Genus *Texananus* Ball.
*areolatus* (Ball). Uncommon. Butler, Riley Co. KS: July.
*decorus* (Osborn and Ball). Rare. Riley Co. KS.

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## Literature Cited

Anderson, K. L. 1953. Utilization of grasslands in the Flint Hills of Kansas. J. Range Management 6:86–93.

Anderson, K. L., and C. L. Fly. 1955. Vegetation-soil relationships in Flint Hills bluestem pastures. J. Range Management 8:163–169.

Baldridge, R. L. 1969. Parasites in leafhoppers from Kansas grasslands (Homoptera: Cicadellidae). Unpubl. M.S. thesis, Kansas State University, Manhattan, Kansas. 85 pp.

Blocker, H. D., T. L. Harvey, and J. L. Launchbaugh. 1972. Grassland leafhoppers. Leafhopper populations of upland seeded pastures at Hays, Kansas. Ann. Entomol. Soc. Amer. 65:166–172.

Blocker, H. D., and R. Reed. 1976. Leafhopper populations of a tallgrass prairie (Homoptera: Cicadellidae): Collecting procedures and population estimates. J. Kans. Entomol. Soc. 49:145–154.

Crevecoeur, F. F. 1905. Additions to the list of the hemipterous fauna of Kansas. Trans. Kansas Acad. Sci. 19:232–237.

Lawson, P. B. 1920. The Cicadellidae of Kansas. Kansas Univ. Sci. Bull. 12:5–306.

Mason, C. E. 1973. Leafhopper and plant diversity in a Kansas bluestem pasture. Unpubl. Ph.D. dissertation, Kansas State University, Manhattan, Kansas. 71 pp.

Popenoe, E. A. 1885. Contributions to a knowledge of the Hemiptera-fauna of Kansas. Trans. Kansas Acad. Sci. 9:62–64.

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# New Epizoic Suctorea (Protozoa) of the Smooth Softshell Turtle, *Trionyx muticus*, in Northeastern Kansas

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## ABSTRACT

From *aufwuchs* taken from the carapace of a smooth softshell turtle, *Trionyx muticus*, captured near Lawrence, Kansas, protozoa were observed. Thirty-eight species of Protozoa were identified to generic rank, most of them also to species (Table 1). Among those protozoa were four species of Suctoreans which are distinct from others described in the literature. They are depicted and described here as: *Testudinicola goodrichi* n. sp.; *Testudinicola globovata* n. sp.; *Tokophyra mutica* n. sp.; and *Tokophrya trionyxa* n. sp.

Suctorean Protozoa commonly grow attached to substrates in either marine or fresh waters (Kudo, 1966), often being epizoic on other aquatic sessile or motile organisms (Kahl, 1931; Jankowski, 1973). Some species, not found elsewhere, are found attached to the carapace or skin of turtles, or to the *aufwuchs* that is attached to the carapace (Goodrich and Jahn, 1943).

While examining the *aufwuchs* scraped from the carapace of a smooth softshell turtle, *Trionyx muticus*, I have found several suctoreans, four kinds of which are sufficiently different from other described species to warrant their description as new species. Many other protozoa were also found in the *aufwuchs* (Table 1).

## MATERIALS AND METHODS

A smooth softshell turtle, *Trionyx muticus*, was captured near the Kaw River (Kansas River) near Lawrence, Kansas, U.S.A. Some of the *aufwuchs* was scraped from the carapace and placed in some water from the river.[1] This sample was brought to the laboratory at the University of Kan-

[1] This sample of *aufwuchs* and the protozoa in it were brought to my attention by Michael Plummer (then a student in the University of Kansas) in October, 1973. Recent comparisons of sketches and measurements of these organisms made then with other suctoreans have convinced me that they are undescribed species.

Table 1. Protozoa in *aufwuchs* from *Trionyx muticus*.

PHYLUM MASTIGOPHORA
- Subphylum Phytomastigophora
  - Class Chrysomonadea
    - Order Ochromonadida
      - Family Ochromonadidae
        - *Ochromonas* sp.
  - Class Euglenea
    - Order Euglenida
      - Family Euglenidae
        - *Euglena deses*
        - *Euglena mutabilis*
    - Order Peranemida
      - Family Peranemidae
        - *Peranema trichophorum*
      - Family Petalomonadidae
        - *Petalomonas mediocanellata*
- Subphylum Zoomastigophora
  - Class Protomastigea
    - Order Bodonida
      - Family Bodonidae
        - *Bodo minima*
        - *Rhynchomonas nasutum*

PHYLUM SARCODINA
- Subphylum Autotracta
  - Class Actinopodea
    - Order Heliozoida
      - *Actinophrys* sp.
- Subphylum Hydraulea
  - Class Cyclea
    - Superorder Lobeda
      - Order Granulopodida
        - Family Difflugiidae
          - *Difflugia globulosa*
      - Order Eruptina
        - Family Hartmannellidae
          - *Hartmannella* sp.
        - Family Vahlkampfiidae
          - *Vahlkampfia* sp.
      - Order Conopodida
        - Family Acanthamoebidae
          - *Acanthamoeba castellanii*
        - Family Mayorellidae
          - *Mayorella leidyi*
          - *Mayorella* sp. 1
          - *Mayorella* sp. 2
          - *Vexillifera* sp. 1
          - *Vexillifera* sp. 2
      - Order Pharopodida
        - Family Vannellidae
          - *Vannella* sp. 1
          - *Vannella* sp. 2
      - Order Thecida
        - Family Thecamoebidae
          - *Thecamoeba sphaeronucleolus*
        - Family Striamoebidae
          - *Striamoeba striata*

PHYLUM CILIOPHORA
- Subphylum Kinetoframinophora
  - Class Suctorea
    - Order Endogenida
      - Family Trichophryidae
        - *Trichophrya epistylidis*
      - Family Dendrosomatidae
        - *Testudinicola goodrichi* n. sp.
        - *Testudinicola globovata* n. sp.
        - *Tokophrya mutica* n. sp.
        - *Tokophrya trionyxa* n. sp.
  - Class Hypostomea
    - Order Cyrtophorida
      - Family Chilodonellidae
        - *Chilodonella cucullulus*
  - Class Gymnostomea
    - Order Karyorelictida
      - Family Loxodidae
        - *Loxodes magnus*
      - Family Geleiidae
        - *Geleia* sp.
    - Order Pleurostomatida
      - Family Amphileptidae
        - *Amphileptus* sp.
        - *Loxophyllum meleagridis*
- Subphylum Oligohymenophora
  - Class Hymenostomea
    - Order Hymenostomatida
      - Family Tetrahymenidae
        - *Tetrahymena pyriformis**
    - Order Scuticociliatida
      - Family Cyclidiidae
        - *Cyclidium* sp.
  - Class Peritrichea
    - Order Sessilida
      - Suborder Aloricina
        - Family Epistylididae
          - *Epistylis niagarae*
          - *Epistylis finleyi*
          - *Epistylis bishopi*
          - *Epistylis plummeri*
          - *Opercularia jahni*

* It was not possible to determine which of the *Tetrahymena* group of species this organism is, hence the use of this "older" name.

Table 1. Continued.

| |
|---|
| Subphylum Polyhymenophora |
| Class Hypotrichea |
| Order Stichotrichida |
| Family Spirofilidae |
| *Kahliella* sp. |
| Order Sporadotrichida |
| Family Oxytrichidae |
| *Gastrostyla* sp. |

sas where it was kept in a glass jar, covered but not sealed, and daily observations were made, microscopically, during a period of two weeks to record the various species of Protozoa in the sample. No attempt was made to identify the many kinds of bacteria and algae also present.

For the suctoreans found, at least 50 specimens of each species were carefully observed and measured.

Protozoa were identified from available keys and research papers (e.g., Kudo, 1966; Jahn, Bovee and Jahn, 1979; Page, 1976; Corliss, 1979; Johnson, 1944; Bovee, 1970; Allegre and Jahn, 1943).

## Observations

Of the many Protozoa present in the sample, 38 were identified to generic name and most of those to the species, as well (Table 1). Other protozoa seen too briefly or infrequently to be accurately identified are omitted. Included in the list are 5 suctoreans and 5 peritrichs. Four of the peritrichs have been described elsewhere as new species (Bovee, 1976). Classification used in Table 1 follows that of Jahn, Bovee and Jahn (1979). One species of suctorean was identified as *Trichophrya epistylidis* Clap. et Lach. The others are described below as new species.

### *Testudinicola goodrichi* n. sp. (Fig. 1)

*Diagnosis.* Adult body 55 to 85 μm long, mean length 65 μm; 35 to 60 μm wide, mean width 45 μm. Body shaped like an inverted pear on a short, cylindrical foot (*not* a stalk); lower ⅔ of the body ridged (7 to 10 ridges) vertically, upper ⅓ a hemispherical "cap" 40 to 60 μm diameter, mean, 44 μm. Body naked or with attached debris. Tentacles 25 to 35 μm long, 1.5 μm diameter, with expanded tip 2.25 μm diameter, on the dome-shaped cap as a group of 10 to 12 distributed more or less evenly on the cap. Macronucleus ribbon-shaped, about 3 μm wide, with rounded ends, 20 to 30 μm long, bent or coiled; micronucleus globular, about 3 μm diameter, near the

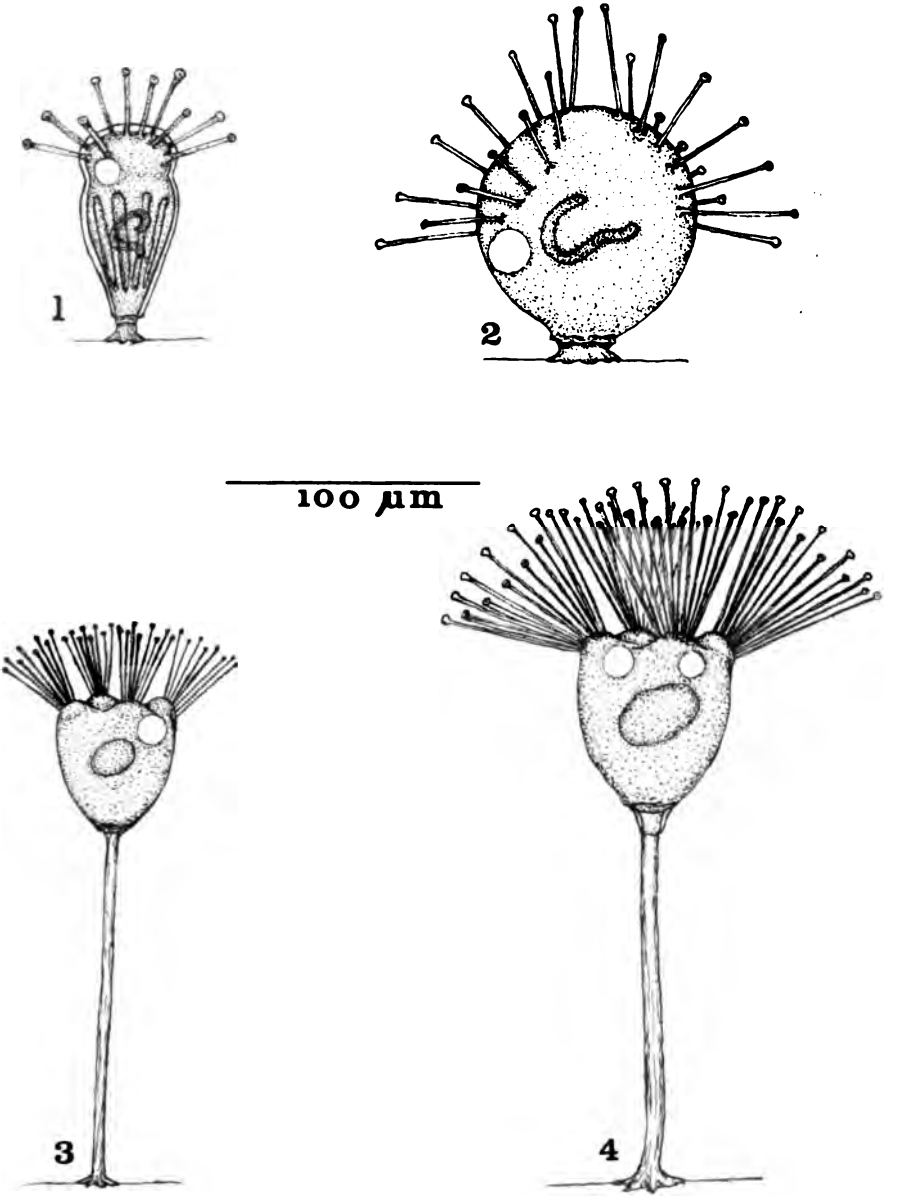


Fig. 1. *Testudinicola goodrichi* n. sp.; Fig. 2. *Testudinicola globovata* n. sp.; Fig. 3. *Tokophrya mutica* n. sp.; Fig. 4. *Tokophrya trionyxa* n. sp.

macronucleus. Water-expelling vesicle ("contractile vacuole") near base of dome-shaped cap. Usually attached to stalks of *Epistylis* spp. or to algal filaments or to the carapace of the turtle. Division, by budding; ciliated larva not seen. Named in honor of James P. Goodrich, deceased, who named new suctoreans from turtles.

*Testudinicola globovata* n. sp. (Fig. 2)

Adult body nearly globular, slightly ovate lengthwise, on a short foot (*not* a stalk), 500 to 100 μm long, 60 to 80 μm wide, not ridged, with or without attached debris. Tentacles 50 to 60 μm long, 1.75 μm diameter, with expanded tip 2.25 μm diameter, in a group of 22 to 24, more or less divided into two clusters on the upper half of the body. Macronucleus ribbon-shaped, bent or twisted, 50 to 60 μm long, about 3 μm wide, with rounded ends; micronucleus globular, indistinct, usually near center of body. Water-expelling vesicle near edge of body, about half way down the side. Usually attached to stalks of *Epistylis* spp., or to other filamentous substrates that are attached to the carapace of the turtle. Division by budding; ciliated larvae not seen.

*Tokophrya mutica* n. sp. (Fig. 3)

Adult body shaped like a broad, inverted pear with four mounds at the upper end, each of which bears a group of tentacles. Body 40 to 55 μm long, 30 to 42 μm wide, mean 50 × 37 μm, often indented to form 4 ridges, each ridge below a group of tentacles. Stalk 120 to 150 μm long, mean 136 μm, diameter about 8 μm. Tentacles each 33 to 39 μm long, 1.5 μm diameter, with expanded tip about 2 μm diameter, four groups, eight tentacles per group. Macronucleus spherical to ellipsoidal, about 30 μm diameter; micronucleus not seen. Many food vesicles. One to 3 water-expelling vesicles, near upper surface. Division by budding; ciliated larvae not seen. Attached to stalks of *Epistylis* spp. or to carapace of the soft shelled turtle.

*Tokophrya trionyxa* n. sp. (Fig. 4)

Adult similar to *T. mutica*, but larger, body broadly ovate to nearly globular, upper surface divided into four mounds, each bearing a group of tentacles. Body 68 to 80 μm long, mean length 72 μm; 60 to 70 μm wide, mean width 66 μm. Body supported on a stalk, 122 to 148 μm long, mean length 132 μm, diameter of stalk 11 to 12 μm. Tentacles each 50 to 62 μm long, usually about 55 μm, about 2.50 μm diameter; 12 tentacles in each of 4 groups, one group to each mound on the upper surface of the body. Macronucleus more or less centrally placed in the body, obovate to irregular, about 40 μm wide; micronucleus not seen, obscured by food vesicles. Many food vesicles. One to 4 water-expelling vesicles present at any one time,

one appearing at the base of each mound near the upper surface of the body. Division by budding; ciliated larvae not seen. Attached, usually, to the stalks of *Epistylis* spp.

## Discussion

The new species of Suctoreans described above resemble other known species, but can readily be distinguished from them.

*Testudinicola goodrichi* n. sp. resembles *T.* (*Anarma*[2]) *multiruga* (Goodrich and Jahn, 1943) but is smaller. The body of *T. goodrichi* is relatively narrower at the base and relatively broader at the top than is that of *T. multiruga*. The tentacles of *T. goodrichi* are shorter and relatively shorter to the body (25 to 35 μm long, about half the length of the body), while those of *T. multiruga* are about the same length as its body (70 to 150 μm). The two species are apparently related, but distinct.

*Testudinicola globovata* n. sp. is distinct from the above-compared two species, lacking the vertical ridges those other species have. Its tentacles are both longer and thicker than those of *T. goodrichi*, but are shorter than those of *T. multiruga*. The tentacles of each of the three species may appear as a single group, more or less evenly distributed on the upper surface, or as two groups of more or less equal numbers, on *T. goodrichi* as two groups of about 5 each, on *T. globovata* as two groups of 12 each. Goodrich and Jahn (1943) noted two groups of tentacles on *T.* (*Anarma*) *brevis*, with 18 tentacles in each group. One of their sketches of *T. multiruga* show 27 tentacles in two approximate groups on an adult body and a bud with 14 tentacles.

The two new *Tokophrya* spp. are clearly distinct from one another as well as from *T. quadripartita* Cl. & Lach. as depicted by Goodrich and Jahn (1943) from specimens collected on the turtle *Chrysemys picta bellii* from Iowa. *T. trionyxa* n. sp. is about the same size as *T. quadripartita*, but the former has 12 tentacles per group and the latter, 8. The stalk of *T. trionyxa* is about half the length of that of *T. quadripartita*. *Tokophyra mutica* n. sp. is smaller than either *T. trionyxa* or *T. quadripartita*. Although *T. mutica* has the same number of tentacles per group as *T. quadripartita*, the tentacles of *T. mutica* are much shorter than those of *T. quadripartita*. The tentacles of *T. mutica* are shorter and more slender than are those of the other two *Trichophyra* spp. The body of *T. trionyxa* is smaller than that of *T. quadripartita* but larger than that of *T. mutica*.

It is probable that a concerted search for suctoreans on other species of turtles would reveal other as-yet-unknown species.

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[2] Janowski (1973) has placed these suctoreans of the genus *Anarma* that have a foot in the genus *Testudinicola*. His classification is followed here.

## Literature Cited

Allegre, C. F., and T. L. Jahn. 1943. A survey of the genus *Phacus* Dujardin (Protozoa: Euglenoidina). Trans. Amer. Microscop. Soc. 62:233–244.

Bovee, E. C. 1970. The lobose amebas. I. A key to the suborder Conopodina Bovee & Jahn, 1966 and descriptions of thirteen new or little-known *Mayorella* spp. Arch. Protistenk. 112:178–227.

Bovee, E. C. 1976. New epizoic peritrichs of the soft shelled turtle, *Trionyx muticus*. Trans. Amer. Microscop. Soc. 95:682–687.

Corliss, J. O. 1979. The Ciliated Protozoa, 2nd ed. Pergamon Press, Oxford. 455 pp.

Goodrich, J. P., and T. L. Jahn. 1943. Epizoic suctoria (Protozoa) from turtles. Trans. Amer. Microscop. Soc. 62:245–253.

Jahn, T. L., E. C. Bovee, and F. F. Jahn. 1979. How to Know the Protozoa, 2nd ed. W. C. Brown, Dubuque, Iowa. 252 pp.

Jankowski, A. W. 1973. Taxonomic sketch, class Suctoria C. & L., 1858. Akad. Nauk. S.S.S.R. Zool. Inst. March 1973:30–31. (In Russian).

Johnson, L. P. 1944. The Euglenae of Iowa. Trans. Amer. Microscop. Soc. 63:97–135.

Kahl, A. 1931–1935. Urtiere oder Protozoa. I. Wimpertiere oder Ciliata (Infusoria). In: Dahl, F., ed. Die Tierwelt Deutschlands. G. Fischer, Jena. 1–864.

Kudo, R. R. 1966. Protozoology, 5th ed. Charles C. Thomas, Springfield, Ill. 1175 pp.

Page, F. C. 1976. An Illustrated Key to Freshwater and Soil Amoebae. Sci. Publ. #34, Freshwater Biol. Assoc., Ambleside, Cumbria, England. 155 pp.

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# Pearl Millet Tolerance to Selected Herbicides[1]

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ABSTRACT

Tolerance of pearl millet to selected herbicides applied and incorporated before planting was evaluated in the field at Manhattan, Kansas, in 1978 and 1979. Atrazine, terbutryn and bifenox only slightly injured pearl millet seedlings. Seedling injury due to propazine was greater in 1978 than in 1979, while injury due to cyanazine was greater in 1979 than in 1978. Plant height and yields were not significantly reduced by triazine herbicides or bifenox either year. Propachlor prevented emergence. Pearl millet exhibited no tolerance to EPTC plus R-25788 and only limited tolerance to butylate plus R-25788.

Growth of pearl millet [*Pennisetum americanum* (L.) Leeke], an important cereal crop in droughty areas of the world, is currently being investigated under Kansas conditions. Large scale production of pearl millet will be possible only if selective herbicides are applied at planting time to control weeds. Panchal et al. (1974) reported that keeping pearl millet weed-free for six weeks after planting prevented yield losses. Atrazine applied before weeds or millet emerged increased yields 28 (Tomer and Singh, 1973), 100 (Panchal et al., 1974), and 150 percent (Jain et al., 1971). Yadav et al. (1978) reported that yields of pearl millet treated with atrazine at 0.8 kg/ha at planting time were equivalent to yields from plots kept weed-free by hand weeding. Ashrof et al. (1977), however, observed that atrazine at 0.8 kg/ha (the same rate) reduced shoot and root growth and chlorophyll content of pearl millet.

Research pertaining to chemical weed control in pearl millet has focused on herbicides used in grain sorghum [*Sorghum bicolor* (L.) Moench] production.

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Objectives of the research reported here were to determine 1) if pearl millet grown under Kansas's conditions tolerates herbicides used in sorghum production and 2) if herbicides phytotoxic to sorghum also are phytotoxic to pearl millet.

## Methods and Materials

Tolerance of pearl millet to selected herbicides was evaluated at the same site at Manhattan, Kansas in 1978 and in 1979. Conventional methods for seedbed preparation were used on a Reading silt loam soil (fine, mixed, mesic, typic Argiudolls) with 2.6 percent organic matter content and a pH of 6.3. Herbicides were applied June 5, 1978, and June 12, 1979, with a tractor-mounted sprayer equipped with tapered flat-fan nozzles with water as a carrier at a volume of 1.87 L/ha and pressure of 1.2 kg/cm$^2$. Treatments included triazine herbicides (atrazine, propazine, cyanazine, or terbutryn), a diphenylether herbicide (bifenox), and an acetanilide herbicide (propachlor) alone and in combination with atrazine, bifenox, or a substituted urea herbicide (linuron). Herbicides were applied at rates recommended for grain sorghum. Thiocarbamate herbicides (EPTC or butylate) in combination with protectant (R-25788) also were applied to determine their efficacy in controlling volunteer millet. Herbicides were immediately incorporated 7.6 cm deep with a power-driven rotary tiller. Simultaneous planting of 'RMP 1' pearl millet 2.5-cm deep and furrow application of the insecticide carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) were within eight hours after herbicide application.

The plots consisted of four rows each 9 meters long and 76 cm wide kept weed free by occasional hand hoeing. Data were collected from the center two rows of each plot and consisted of visual injury ratings and plant height. Grain yields were obtained after millet heads were harvested by hand in early October, dried, and threshed.

Data reported represent means of three replications in a randomized complete block design.

## Results and Discussion

Atrazine, terbutryn, and bifenox applications caused only slight injury in pearl millet seedlings either year (Table 1). Seedling injury was greater when cyanazine or propazine was applied in 1978 or cyanazine in 1979. Propachlor applied alone or in combination with other herbicides prevented pearl millet from emerging both years. EPTC plus protectant R-25788 applied as a tank mix combination also prevented millet emergence, while butylate plus R-25788 severely reduced but did not completely prevent emergence.

Atrazine, propazine, terbutryn, or bifenox did not significantly reduce plant height or yields either year. Cyanazine also did not significantly reduce yields even though it severely injured seedlings in 1979. Some of the pearl

Table 1. Seedling injury and growth of pearl millet treated with indicated herbicides at Manhattan, KS in 1978 and 1979.

| Herbicide | Rate | Injury rating[a,b] | | Height[a] | | Yield[a] | |
|---|---|---|---|---|---|---|---|
| | | 1978 | 1979 | 1978 | 1979 | 1978 | 1979 |
| | (kg/ha) | | | (cm) | | (kg/ha) | |
| Atrazine | 2.4 | 0.10 d | 0.10 c | 113 ab | 160 a | 857 a | 3218 a |
| Propazine | 2.7 | 0.27 c | 0.03 c | 117 ab | 163 a | 920 a | 2984 a |
| Cyanazine | 1.7 | 0.20 cd | 0.50 b | 125 a | 135 a | 1185 a | 2863 a |
| Terbutryn | 2.7 | 0.13 d | 0.10 c | 130 a | 157 a | 1011 a | 2836 a |
| Bifenox | 1.4 | 0.10 d | 0.03 c | 135 a | 166 a | 1662 a | 3138 a |
| Propachlor | 3.4 | 1.00 a | 0.98 a | 0 c | 0 c | 0 c | 0 c |
| Propachlor + atrazine | 3.4 + 1.4 | 1.00 a | 1.00 a | 0 c | 0 c | 0 c | 0 c |
| Propachlor + bifenox | 3.4 + 1.4 | 1.00 a | 1.00 a | 0 c | 0 c | 0 c | 0 c |
| Propachlor + linuron | 3.4 + 1.1 | 1.00 a | 1.00 a | 0 c | 0 c | 0 c | 0 c |
| EPTC + R-25788 | 6.7 + 0.6 | 1.00 a | 1.00 a | 0 c | 0 c | 0 c | 0 c |
| Butylate + R-25788 | 6.7 + 0.3 | 0.63 b | 0.83 a | 7 bc | 30 b | 372 b | 280 b |
| None | — | 0.00 d | 0.00 c | 113 ab | 170 a | 1440 a | 2997 a |

[a] Means within columns followed by common letters do not differ significantly according to Duncan's Multiple Range Test.

[b] Injury ratings taken 10 days after treatment. Rating scale: 0 = no injury, 1.0 = complete death.

millet seedlings that survived butylate applications produced seed. Yields in 1979 exceeded those in 1978 because more rain fell during the 1979 growing season (15.9 cm compared with 9.0 cm in 1978).

Our studies indicate that pearl millet is tolerant of herbicides such as atrazine, propazine, or bifenox that are used to control broadleaf weeds. Tolerance to herbicides like cyanazine, terbutryn, or propachlor used mainly to control grass weeds, was acceptable only for terbutryn. Further studies are necessary to determine if susceptibility to propachlor can be prevented by planting millet several weeks after the herbicide is applied or by herbicide antidotes. Safe use of propachlor would offer options to growers to control grass weeds in pearl millet alone or in pearl millet grown with a leguminous crop.

## Literature Cited

Ashrof, N., R. K. Bhatia, and D. N. Sen. 1977. Toxicity of different pre-emergence herbicides on *Pennisetum typhoideum* Rich. and *Sesamum indicum* Linn. Indian Journal of Weed Science 1:19–23.

Jain, T. C., R. M. Signh, and K. C. Jain. 1971. Effect of atrazine and propazine on weeds and yield of pearl millet. Indian Journal of Weed Science 1:23–27.

Panchal, Y. C., Sastry, and K. S. Krishna. 1974. Cereal crops should be weed-free for the first 4–6 weeks after sowing to ensure good yields. Current Research Monthly Newsletter (University of Agricultural Sciences, Bangalore, India) 3:51–52.

Tomer, P. S., and R. C. Singh. 1973. Minimum tillage and weed control studies in pearl millet. Indian Journal of Weed Science 2:80–85.

Yadav, D. S., K. B. Singh, V. D. Sharma, P. Vir., N. S. Solanski, and V. Ram. 1978. Studies on the chemical control of weeds in pearl millet under rainfed conditions. Indian Journal of Agricultural Research 2:73–78.

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# Miscellaneous Summer Records of Birds from Southwestern Kansas

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ABSTRACT

Two summers (1978 and 1979) of field research on nongame wildlife in southwestern Kansas have established several new records for both breeding and migratory species of birds. New breeding records were established for the ferruginous hawk (*Buteo regalis*), lesser prairie chicken (*Tympanuchus pallidicinctus*), great-tailed grackle (*Quiscalus mexicanus*), and the field sparrow (*Spizella pusilla*) from Morton County; the American avocet (*Recurvirostra americana*) from Seward and Kearny counties; and the Cassin's sparrow (*Aimophila cassinii*) from Meade County. Species showing increased summer movements and breeding activities include the curve-billed thrasher (*Toxostoma curvirostre*), great-tailed grackle, and the Brewers sparrow (*Spizella breweri*) from Morton County. Sightings of rare species include the ladder-backed woodpecker (*Dendrocopos scalaris*), northern parula warbler (*Parula americana*), Blackburnian warbler (*Dendroica fusca*), and the chestnut-sided warbler (*Dendroica pensylvanica*) from Morton County; and the rose-breasted grosbeak (*Pheucticus ludovicianus*) from Grant County. While some species show distributional increases (e.g. great-tailed grackle) others have shown a decline in this region (e.g. ladder-backed woodpecker). Still not enough is known about other species (e.g. rose-breasted grosbeak, field sparrow) to understand their distributional patterns in southwestern Kansas.

Several studies describe the status and distribution of summer birds in southwestern Kansas (Rising, 1974; Ely and Thompson, 1971; Graber and Graber, 1951). Recent fieldwork in this region has nevertheless resulted in several new breeding and distributional records.

During the summers of 1978 and 1979, while employed by the Kansas Fish and Game Commission, I conducted a nongame research project to

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determine the status and distribution of some rare and peripheral species of birds in southwestern Kansas. This resulted in new breeding records for the curve-billed thrasher, great-tailed grackle, Brewers sparrow, ferruginous hawk, lesser prairie chicken, and American avocet. Other records for species such as the rose-breasted grosbeak, Cassin's sparrow, and the field sparrow serve to help understand their distributions in this region. Included here are records for such species as the ladder-backed woodpecker, northern parula warbler, Blackburnian warbler, and chestnut-sided warbler which are considered rare in southwestern Kansas. The following species deserve close attention by field ornithologists in the future.

*Ferruginous Hawk.* This hawk is an uncommon summer resident in western Kansas with most of the breeding records coming from counties north of the Arkansas River (Johnston, 1964). On 4 June 1979 a nest with two half grown nestlings was discovered in Morton County in far southwestern Kansas. The nest was 10 ft. up in a small stand of trees (*Morus*) surrounded by Sand sagebrush (*Artemisia filifolia*)-grasslands. This constitutes the first breeding record of this hawk for Morton County.

*Lesser Prairie Chicken.* This species is reported to be fairly common in the southwestern counties of Morton, Meade, and Ford but actual breeding records from this region are few (Rising, 1974). Two nests of this species were found 2½ mi. SE of Wilburton, Morton County, in an area of sandhills covered with sagebrush, forbs, and sparse grasses. One nest, discovered on 18 May 1979, was placed beneath a sagebrush on the ground concealed by tufts of new grass. It held 12 eggs. On 1 June 1979 this nest held 12 recently hatched nestlings no more than a few hours old. A nest discovered on 26 May 1979 contained 13 eggs and was placed only 200 yards from the first nest.

*American Avocet.* This bird is locally common throughout southwestern Kansas around marshes and ponds. Breeding records exist for Meade and Finney counties (Rising, 1974). On 21 June 1979 four adults and a nest were found 6½ mi. SE of Satana, Seward County. The nest, containing one egg, was found in a recently plowed field near a temporary pond produced by over-flow from an irrigation sprinkler. On 28 June 1979 46 adults were found at a shallow water basin basin which was at one time Kearny County State Lake, but has now been abandoned. Located 4 mi. N of Deerfield, Kearny County, the basin was 2–3 ft. deep with much emergent vegetation and an abundance of aquatic invertebrates. One avocet nest with 4 eggs was found 6 yards from the water among scattered weeds (*Polygonum*). These are the first breeding records of this species for Seward and Kearny counties.

*Ladder-backed Woodpecker.* This species was fairly common along the Cimarron River during the spring of 1950 (Graber and Graber, 1951), but was not observed again until the summers of 1967 and 1968 when birds were observed and one collected along the Cimarron River in Morton County

(Ely and Thompson, 1971). During the period 27 May to 14 August 1978 this woodpecker was not observed in Morton County. On 2 August 1979 a male ladder-backed woodpecker was seen foraging alone 4 mi. N and 4 mi. W of Rolla on the Cimarron River in Morton County. This was the only individual of this species seen during the summer of 1979 and probably represents a post-breeding wanderer.

*Curve-billed Thrasher.* This species is not mentioned by either Johnston (1964) or Rising (1974). However, it has been seen repeatedly in central and southwestern Kansas since the early 1960's (Ely and Davis, 1968). Breeding records are reported from Kearny and Morton counties (Schwilling, 1980). During the summer of 1978 I located a nest 8½ mi. N and 3½ mi. E of Rolla, Morton County. On 24 June 1978 a thrasher was incubating one egg in this nest located in a large cholla cactus (*Opuntia*) along the Cimarron River. At this same locality on 4 June 1979 I found a nest with 3 nestlings in the same cactus that was used during the summer of 1978. Repeated visits to this nest site resulted in finding a new nest built in the same cactus which held 2 eggs on 26 June. On 28 July I found a new nest built in the cactus (the third nest this season in the same cactus) containing 3 well incubated eggs. On 9 August this nest held 3 half grown nestlings and on 16 August two nestlings were at the nest in fledgling condition. These repeated nestings in the same cholla cactus may represent a case of double-broodedness or renesting after repeated nest failures. Schwilling (1980) found another pair of thrashers at a completed nest in a cholla cactus 4 mi. N of Montezuma in Gray County on 14 June 1979. This thrasher depends on the cholla cactus for nesting sites (Bent, 1963) and the present scarcity and possible future increases of this cactus on rangeland in southwestern Kansas will no doubt determine the future of this thrasher in this region.

*Northern Parula Warbler.* A singing male was observed on 3 June 1978 along the Cimarron River, 8 mi. N and 2 mi. E of Elkhart, Morton County. The day was cloudy with light rain. This species is a common transient and summer resident in eastern Kansas (Johnston, 1964), but was not seen by Rising (1974) in western Kansas. This is the first record of this species for Morton County.

*Blackburnian Warbler.* A male in breeding plumage was observed foraging in willow thickets along the Cimarron River, 7½ mi. N and 1 mi. W of Elkhart, Morton County. This species is a rare transient in western Kansas (Johnston, 1965). The day, 23 May 1979, was cloudy and cool with intermittent rain.

*Chestnut-sided Warbler.* On 24 May 1979 a male was observed foraging in willow thickets at Middle Springs in Morton County. This species is a rare transient in western Kansas (Johnston, 1965) and was not seen in western Kansas by Rising (1974).

*Great-tailed Grackle.* The spread of this species into Oklahoma and south-

central Kansas during the last 30 years has been well documented (Davis, 1975). On 25 June 1978 a female grackle was seen on a nest, 15 ft. up in an elm tree (*Ulmus*) in the town of Elkhart, Morton County. An adult male was also seen at this locality. During the summer of 1979 this grackle was not observed in Morton County, however small flocks were observed in Grant County (7 June), Seward County (21 June), and Meade County (21 June) indicating movement into southwestern Kansas. It was not observed by Rising (1974) in his work of the region.

*Rose-breasted Grosbeak.* This species is a transient and summer resident in eastern Kansas (Johnston, 1964) and a low density breeder in northwestern Kansas (Rising, 1974). In southwestern Kansas a male, probably a transient, was observed on the Cimarron River in Morton County on 24 May 1978. On 21 June 1979 3 singing males were counted along a 1 mi. section of the Cimarron River, 12 mi. S Ulysses, Grant County. The habitat was composed of tall (30–50 ft.) dense cottonwoods (*Populus*) along both banks of the river. These may have been breeding birds, however, no nests or females were seen.

*Cassin's Sparrow.* This sparrow is a common breeder throughout southwestern Kansas wherever sand sagebrush-grasslands occur. Breeding records occur for Morton, Finney, Seward, and Stevens counties (Rising, 1974), and also Hamilton, Kearny, and Comanche counties (Johnston, 1964). I found this bird in sandhills or river breaks covered with sand sagebrush, bunch grasses (*Eragrostis* sp., *Schizachyrium scoparium*), and forbs (*Helianthus, Chenopodium*). On 6 June 1978 two nests were found 3 mi. SE of Wilburton, Morton County. Both nests were placed 3–5 in. up in a sagebrush. One nest held 4 eggs while the other nest held 5 eggs. In this same locality a third nest with 5 eggs was found on 12 June 1978. On 2 June 1979 a nest with 5 eggs was discovered in Morton County, in similar sagebrush habitat. On 10 July 1979 in sagebrush-grassland, 18 mi. SW of Meade, Meade County, a nest was found containing 2 Cassin's sparrow eggs and 3 brown-headed cowbird (*Molothrus ater*) eggs. This constitutes the first breeding record of this sparrow for Meade County. This sparrow was found to be common in several localities in southwestern Kansas such as along Bear Creek in Stanton County (5 June 1979) along the Cimarron River in Stevens County (20 June 1979) and Grant County (21 June 1979); and on grasslands in southern Clark County (21 July 1979).

*Brewers Sparrow.* This sparrow is a common migrant in western Kansas most often seen on sagebrush-grasslands or riparian habitats (Johnston, 1964). Two summer records (Easterla, 1964) of this bird had suggested the possibility of it breeding in southwestern Kansas. On 17 and 19 May 1978, 6 singing males and a nest with four eggs were discovered in sagebrush-grasslands 5½ mi. N and 9½ mi. E Elkhart, Morton County (Thompson et al., 1980). Extensive fieldwork conducted in Morton County during the sum-

mer of 1979 resulted in the discovery of 24 singing males, 4 active nests, and 2 abandoned nests. On 27 May 1979 two of the active nests held a clutch of 4 eggs and a third nest contained 3 eggs plus one brown-headed cowbird egg. On 3 June one of the nests held 3 small nestlings, a second nest held 4 eggs, and the third nest held 2 Brewers sparrow nestlings and one cowbird nestling. On 7 June all 3 of these nests were empty but still intact. The fourth active nest, discovered on 9 June, held 2 fledglings. This sparrow was not observed in any other county during the summer of 1979, although similar sagebrush-grasslands exist throughout southwestern Kansas.

*Field Sparrow.* This species is considered a common summer resident throughout Kansas (Johnston, 1964) however there are few actual summer records for extreme southwestern Kansas. During the summer of 1978 I found singing males in 6 localities along the Cimarron River in Morton County. These birds were found in sandy flood plain areas of dense salt cedar (*Tamarix*) and rabbitbrush (*Chrysothamnus*) interspersed with scattered cottonwoods. No nests or juvenile birds were seen during this period. On 19 June 1979, in a flood plain area of dense salt cedars 5 mi. N and 5 mi. W Elkhart, Morton County, two adults and two juveniles were watched as they foraged through the salt cedars. During the summer of 1979 I found this sparrow to be locally common along the Cimarron River. In Clark County on 12 July I found them common, as did Rising (1974), in thickets of salt cedar and sand plum (*Prunus*). As one progresses west along the Cimarron River from Clark County this sparrow becomes less common and more localized. On 11 July, in a 13 mile auto census of birds along the Cimarron River in southern Meade County, I counted only 5 singing males while making stops every ½ mile. The habitat in this area is almost devoid of cottonwoods but instead consisted of dense thickets of salt cedar, sand plum, and rabbitbrush. A lush meadow-like grassland of salt grass (*Distichlis*) and Alkali Sacaton (*Sporobolus airoides*) provides the ground cover in this area. In Seward County on 22 June only 2 singing males were observed in a 1½ mile walk along the Cimarron River, 13 mi. NW Liberal. The habitat here was composed of dense cottonwood and willow (*Salix*) saplings hugging the banks of the river. I observed this sparrow only once on the Arkansas River, 3 mi. W Ingalls, Gray County, when one singing male was observed in salt cedar thickets on 29 June 1979. It is considered a common summer resident in nearby Finney County (Rising, 1974).

## Literature Cited

Bent, A. C. 1963. Life Histories of North American Nuthatches, Wrens, Thrashers, and their Allies. New York, Dover.

Davis, W. M. 1975. The Great-tailed Grackle in Oklahoma. Bull. Oklahoma Ornith. Soc. 8:9–18.

Easterla, D. A. 1964. Another summer record of the Brewer Sparrow in Kansas. Bull. Kansas Ornith. Soc. 15:19.

Ely, C. A., and J. A. Davis. 1968. Records of Curve-billed Thrasher from Kansas. Bull. Kansas Ornith. Soc. 19:14–15.

Ely, C. A., and M. C. Thompson. 1971. Distributional notes from southwestern Kansas. Bull. Kansas Ornith. Soc. 22:9–11.

Graber, R., and J. Graber. 1951. Notes on the birds of southwestern Kansas. Trans. Kansas Acad. Sci. 54:145–174.

Johnston, R. F. 1964. The breeding birds of Kansas. Univ. of Kansas Publs. Mus. Nat. Hist. 12:574–655.

Johnston, R. F. 1965. A Directory to the Birds of Kansas. Univ. of Kansas Mus. Nat. Hist. Misc. Publ. No. 41.

Rising, J. D. 1974. The status and faunal affinities of the summer birds of western Kansas. Univ. Kansas Sci. Bull. 50:347–388.

Schwilling, M. D. 1980. A review of Curve-billed Thrasher records from Kansas. Bull. Kansas Ornith. Soc. 31:24–25.

Thompson, M. C., M. D. Schwilling, and J. A. White. 1980. New distributional records for the state of Kansas. Bull. Kansas Ornith. Soc. 31:26–27.

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# Metabolizable Energy in Four Seeds Fed to Cardinals[1]

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ABSTRACT

Metabolizable energy was determined for four seeds fed to cardinals (*Cardinalis cardinalis*) confined in an environmental chamber under simulated winter conditions. Gross energy of the seeds used ranged from 4.94 to 6.92 kcal/g and metabolizable energy ranged from 2.66 to 5.86 kcal/g. The efficiency of cardinals to metabolize the energy contained in the different seeds ranged from 53.9 to 84.7%. For energetic studies of wild granivorous avifauna to be meaningful, they must be accompanied by detailed food habit studies and determinations of seed-specific metabolic efficiencies.

Gross energy contents of many seeds eaten by birds have been determined and published (Golley, 1959, Kendeigh and West, 1965, Johnson and Robel, 1968, Robel, 1973), but records of metabolizable energy in seeds are less common. Willson and Harmeson (1973) determined the metabolizable energy in six seeds fed to cardinals (*Cardinalis cardinalis*). We determined metabolic efficiency of cardinals for four additional seeds.

Wild adult cardinals were mist-netted within 10 km of Manhattan, Kansas, in October, placed in an aviary for two weeks, then individually confined in cages in an environmental chamber at 5°C, 50% R.H., and 10L:14D photoperiod. Cages, 33 × 21 × 24 cm, were fitted with removable floors of 13-mm hardware cloth raised 2 cm above the cage bottom to minimize coprophagy.

Seeds of roundhead lespedeza (*Lespedeza capitata*), thickspike gayfeather (*Liatrus pycnostachya*), maximilian sunflower (*Helianthus maximiliani*), and sawtooth sunflower (*H. grosseserratus*) were obtained from the Manhattan Plant Materials Center of the U.S. Soil Conservation Service. These plants were being propogated by the Soil Conservation Service for use in

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Table 1. Metabolizable-energy data from four feeding trials with indicated seeds each fed to two adult cardinals separately.

| Seed | Energy content (kcal/g) | Energy ingested (kcal/bird/day) | Energy excreted (kcal/bird/day) | Metabolic efficiency (%) | Metabolizable energy (kcal/g) |
|---|---|---|---|---|---|
| Roundhead lespedeza | 4.94 | 6.99 | 3.22 | 53.9 | 2.66 |
| Thickspike gayfeather | 5.94 | 8.61 | 2.02 | 76.6 | 4.55 |
| Sawtooth sunflower | 6.53 | 38.76 | 7.17 | 81.5 | 5.33 |
| Maximilian sunflower | 6.92 | 39.76 | 6.08 | 84.7 | 5.86 |

wildlife plantings. An ad libitum ration of each seed was provided separately to two weight-stable cardinals during two consecutive 2-day periods. Energy data (feed and excreta) were collected at the end of each 2-day period and processed according to procedures described by Case and Robel (1974:639). Energetic data were adjusted for body weight loss by subtracting 0.356 × weight loss (g) from the excretory energy (Clement 1970:25). Data were analyzed by analysis of variance and Duncan's New Multiple Range Test ($\alpha = 0.05$).

Pre-feeding trial weights of cardinals averaged 42 g. Cardinals fed roundhead lespedeza lost 5.4 g/day (13% of pre-trial weight) and those fed thickspike gayfeather lost 5.1 g/day (12% of pre-trial weight). That contrasts with weight gains by cardinals fed sunflower seeds, e.g., 0.4 g/day increase for birds on maximilian sunflower and 0.6 g/day for birds fed sawtooth sunflower seeds.

Weight losses by cardinals on lespedeza and gayfeather seeds were caused by low intake of these seeds during the feeding trials. Cardinals consumed an average of only 1.4 g/day of lespedeza or gayfeather seeds, significantly less ($P < 0.05$) than the 5.8 g/day of sunflower seeds.

Gross energy content of the four seeds tested ranged from 4.94 kcal/g for lespedeza to 6.92 kcal/g for maximilian sunflower (Table 1). Cardinals consumed more ($P < 0.05$) energy when offered sunflower seeds than lespedeza or gayfeather seeds. The metabolic efficiency for roundhead lespedeza seeds was 53.9% lower ($P < 0.05$) than the 76.6% for thickspike gayfeather seeds. Metabolic efficiencies for the sunflower seeds were higher ($P < 0.05$) than for lespedeza or gayfeather; the 81.5% metabolic efficiency for sawtooth sunflower seeds did not differ ($P > 0.05$) from the 84.7% for maximilian seeds. The metabolizable energy (kcal/g) in lespedeza or gayfeather seeds was lower ($P < 0.05$) than in seeds of sawtooth or maximilian sunflowers (Table 1).

Our study was not designed to measure feeding preferences of cardinals, however, birds on ad libitum rations of roundhead lespedeza or thickspike gayfeather seeds consumed about 75% less food than birds offered sunflow-

er seeds. From this we conclude that cardinals prefer sunflower seeds to seeds of roundhead lespedeza or thickspike gayfeather.

Data from our study, and the study of Willson and Harmeson (1973) suggest that different species of birds might metabolize the same seeds with differing efficiency. For example, our cardinals used 81 to 84% of the energy in sunflower seeds, and Willson and Harmeson (1973) reported an 80% metabolic efficiency for sunflower seeds by cardinals. However, Robel et al. (1979) found that bobwhites (*Colinus virginianus*) used only 61% of the energy in sunflower seeds. Willson and Harmeson (1973) report 73% utilization of hemp (*Cannabis sativa*) seed energy by cardinals compared with 45% reported by Robel et al. (1979) for bobwhites. For other seeds, different species of birds appear to have similar utilization levels, e.g., Robel et al. (1979) reported 76% utilization of energy in ragweed seeds by bobwhites and Willson and Harmeson (1973) reported 77% by cardinals.

Some of the differences and agreements in energetic variables could result from differences in handling data. We took weight losses into account, but Willson and Harmeson (1973) did not. Significant error can result by diet-derived metabolic wastes in the excreta being supplemented by exogenous excretory energy from the metabolism of body reserves. Much of the variability in the metabolic energy efficiencies reported for cardinals by Willson and Harmeson (1973) may have stemmed from their not considering weight losses in their calculations. More work needs to be done to standardize methodology so comparable data will result.

Our studies, and those of others, indicate that for energetic studies of wild granivorous avifauna to be meaningful, they must be accompanied by detailed food habit studies. Also, it may be necessary to determine seed-specific metabolic efficiencies of different bird species to add precision to field studies of avian energetics.

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## Literature Cited

Case, R. M., and R. J. Robel. 1974. Bioenergetics of the bobwhite. J. Wildl. Manage. 38:638–652.

Clement, T. M., Jr. 1970. Metabolizable energy values of some plant seeds consumed by bobwhite quail in Kansas. M.S. thesis, Kansas State University, Manhattan. 40 pp.

Golley, F. B. 1959. Table of caloric equivalents. Dept. Zool., Univ. Georgia, Athens. 7 pp. (Mimeo)

Johnson, S. R., and R. J. Robel. 1968. Caloric values of seeds from four range sites in northeastern Kansas. Ecology 49:956–961.

Kendeigh, S. C., and G. C. West. 1965. Caloric values of plant seeds eaten by birds. Ecology 46:553–555.

Robel, R. J. 1972. Energy content in seeds. Trans. Kansas Acad. Sci. 75:301–307.

Robel, R. J., A. R. Bisset, T. M. Clement, Jr., A. D. Dayton, and K. L. Morgan. 1979. Metabolizable energy of important foods of bobwhites in Kansas. J. Wildl. Manage. 43:982–987.

Willson, M. F., and J. C. Harmeson. 1973. Seed preferences and digestive efficiency of cardinals and song sparrows. Condor 75:225–234.

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# Book Review

KANSAS PRAIRIE WILDFLOWERS. *Clenton E. Owensby*. 124 pages. Iowa State University Press, Ames. 1980. $15.00 clothbound; $7.95 paperbound.—This pocket-sized volume includes 164 species of wildflowers occurring in Kansas prairies. Unfortunately, the eastern prairies are obviously ignored. The addition of a mere dozen or so species would have added substantially (e.g., *Nemastylis, Polytaenia, Hypoxis, Camassia,* or etc.). For those plants treated each is briefly described in lay terms, the Kansas distribution mapped, and one or more color photograph provided. While the color separation of the photographs is not of the highest quality, it is not so poor as to dramatically detract from the overall quality of the book.

The book is intended as a convenient identification tool for the layperson. Toward this goal the plants are arranged according to flower color and each of these groups is provided with a key based on plant morphology. Considering the large number of plants not covered by such a work one might question the inclusion of keys. Purchasers of the book should be aware that an errata sheet has been printed to correct some of the keys and this should now come with the book. Copies are also available from the press or author.

A few errors I have found in the book include the following: p. 22—the maps for plains larkspur and Illinois bundleflower appear to be reversed; p. 36—*Sisyrinchium campestre* var. *campestre* is named and has blue flowers but var. *kansanum* which has white flowers is illustrated, *S. campestre* does not occur in southwest Kansas as indicated by the map; p. 112—*Asclepias* veridiflora should be *A. viridiflora*.

On the whole *Kansas Prairie Wildflowers* is a well produced book and has been reasonably priced. It will make a fine addition to the library of someone with an interest in Kansas wildflowers.—Ralph E. Brooks, State Biological Survey of Kansas, 2045 Avenue A, Campus West, Lawrence, Kansas 66044.

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# Another Suggested Case of Ophidian Deceptive Mimicry

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ABSTRACT

Recent doubt that resemblances of coral snakes and their look-alikes are due to functional mimicry leaves few convincing cases known of mimicry among snakes. A new case is proposed for *Pituophis l. lineaticollis* and *Crotalus durissus culminatus* of Mexico. The possibility of generic-level mimicry between rattlesnakes (*Crotalus, Sistrurus*) and bullsnakes (*Pituophis*) is suggested, tempered by the same sort of reservation recently expressed for coral snake mimicry—to wit, that the resemblances are non-mimetic convergence resulting from common selection pressures.

The most widely cited cases of reptilian deceptive (Batesian) mimicry involve coral snakes (*Micrurus, Micruroides, Leptomicrurus*) and a number of genera and species of non-venomous (e.g., certain species of *Lampropeltis, Pseudoboa, Simophis, Anilius* and *Pliocercus*) and mildly venomous (e.g., *Erythrolamprus*) species Grobman (1978). However, the criticisms of several recent authors (e.g., Grobman, 1978; MacGregor, 1980) cast serious doubt upon the functional existence of mimicry among coral snakes and their look-alikes. Indeed, MacGregor's (1980) hypothesis that proposed cases of either deceptive or reinforcement (Müllerian) mimicry involving red-marked snakes of crepuscular and nocturnal and/or burrowing habits may more parsimoniously be regarded as cases of convergent selection for pigmentation that serves a disruptive, cryptic function in dim light (when these snakes would most frequently be exposed), rather than as mimicry,

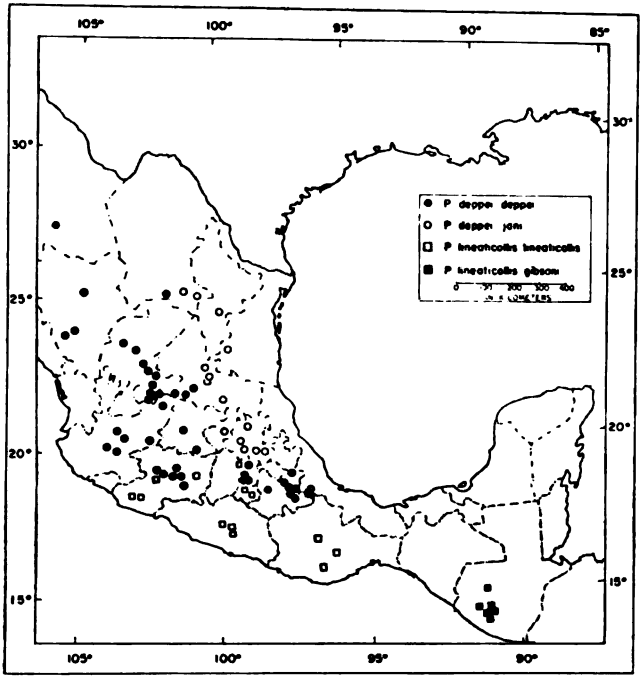


Fig. 1. Distribution of *Pituophis deppei* and *P. lineaticollis* (from Duellman, 1960:603, fig. D).

is not only convincing, but would leave ophiology with few clearcut cases of any sort of mimicry. Orr (1979) provides an excellent review of this complex subject in relation primarily to American snakes.

With the possible discreditation of much of the coral-snake look-alikes as valid examples of mimicry, other examples become of great interest. The suite of 10 oriental species of snakes (9 of *Boiga*, and *Echis carinata*) described by Kroon (1975, following Gans and Latifi, 1973) appears to constitute a valid instance, and we here suggest another of minimal complexity, of two species only (*Crotalus durissus culminatus* Klauber of the family *Viperidae*, and *Pituophis l. lineaticollis* (Cope), of the family Colubridae), exemplifying deceptive mimicry.

In this proposed case, *C. d. culminatus* serves as the noxious model, and *P. l. lineaticollis* (nomenclature of Duellman, 1960) as the mimic. These two taxa have broadly overlapping geographic ranges (Figs. 1, 2), including the more or less xeric subtropical scrub or deciduous forest-edge in Guerrero, Mexico (sight record, primary author), Michoacán, Morelos and Oaxaca. Klauber (1972) supposed the habitat of *C. d. culminatus* to be mainly pine-oak forest (as of Leopold, 1950), but in error; it is properly described in

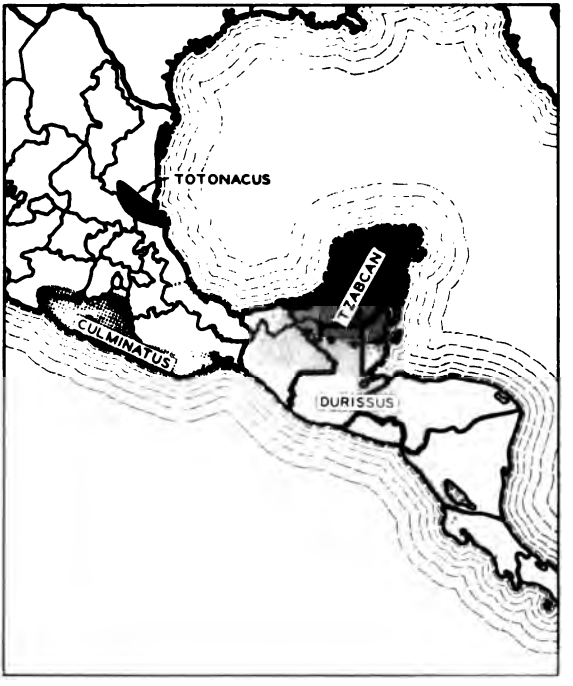


Fig. 2. Distribution of *Crotalus durissus* in Mexico and Central America (from Klauber, 1972:60, fig. 2.4, courtesy University of California Press).

Armstrong and Murphy (1979:11–12), as stated above and in conformance with recent collections by the primary author as well as with recorded localities. Occurrence in the Temperate Pine-oak Forest habitat (Leopold, 1950) is marginal; Leopold's Arid Tropical Scrub Forest is its primary habitat zone.

The resemblances of these taxa are extensive, pertaining to pattern, color and behavior. Both have a grayish brown to ochraceous ground color; a pair of long, paravertebral dark stripes on neck and anterior part of body (Figs. 3, 4); a middorsal series of large, ochraceous, black-bordered spots (quadrangular in *Pituophis*, diamond-shaped in *Crotalus*); smaller lateral dark blotches alternating with the dorsal ones; tail with dark blotches (*Pituophis*) or rings (*Crotalus*); and a creamy whitish venter. Both are large (*Pituophis* to 2 m, *Crotalus* to 1.5 m) and of crepuscular, diurnal or nocturnal activity according to temperature, humidity, season and extent of cloud cover.

Although both species reach large size and themselves are formidable aggressors, certainly juveniles frequently and even adults occasionally are

Fig. 3. *Pituophis l. lineaticollis* (from Gunther, 1894:pl. 47).

confronted with common (shared) aggressors (Wickler, 1968), hence certainly *Pituophis* is subjected to selection pressure favoring mimicry.

The objection to functional mimicry existing in this case because of extreme lethality of the model's venom we regard as weak, since certainly many encounters are either deliberately or accidentally sublethal for the aggressor. Much literature (e.g., Minton and Minton, 1969:24–27) documents the existence of choice at each bite of quantity of venom injected, and certainly some strikes are partially ineffective for numerous reasons. Hence the opportunities for predator learning, and for selection pressure to effect evolution of mimicry, are abundant.

Fig. 4. *Crotalus durissus culminatus* (from Klauber, 1972:69, fig. 2.20, courtesy University of California Press).

It should be noted that the most conspicuous character-state convergence, in the neck stripes, is evident only in *P. lineaticollis* (both subspecies) of its genus, whereas it is present in most subspecies of the very wide-ranging and extensively polytypic *C. durissus*.

Behavioral similarities are remarkable but not limited to the particular taxa dealt with here; they extend to all members of both genera. Nevertheless they must extensively reinforce the pattern mimicry, and there could well be a generic mimicry underlying the specific mimicry here proposed, for the geographic range of *Pituophis*, while extensive, is almost totally overlapped by the even more extensive range of *Crotalus*. Both vibrate the tail strongly (one benefitting also from the presence of a rattle, the other not); both coil the body in defensive postures, assuming an elevated S-shape with the anterior third; both produce a formidable rattling sound—one with a unique epiglottal cartilage, with other with a unique tail rattle (shared with *Sistrurus*, a not-too-distinctive, close relative of *Crotalus*); and both inflate the lungs extensively, increasing the apparent size of body. To be sure, only one of these resemblances (the sound-production) is unique to these two generic groups, at least with such close approximation (other snakes hiss, like *Pituophis*, but not with such a vibratory rattling sound); numerous other snakes vibrate the tail, assume an elevated striking posture and inflate the lungs. These behaviors no doubt reinforce the effectiveness of the unique parallelism in sound-production of *Crotalus* (with *Sistrurus*) and *Pituophis*. The hypothesis that the latter genus evolved as a generic-level mimic of *Crotalus* merits serious consideration. The question is whether these genera exhibit merely behavioral convergence, *sensu* Greene (1979), in response to a shared environmental stress (large hoofed mammals), or functional mimicry.

Unlike the case described by Gans and Latifi (1973) and Kroon (1975),

the present example can involve no other species, for the pattern is unique. Mimicry at the generic level, however, between *Crotalus* (with *Sistrurus*) and *Pituophis*, if it is shown to exist, would involve a complex even more extensive than that described by Kroon.

The question of generic-level mimicry vs. non-mimetic adaptive convergence in rattlesnakes (*Crotalus* and *Sistrurus*) and bullsnakes (*Pituophis*) is remarkably akin to the same question MacGregor (1980) posed for the patterns of coral snakes and their look-alikes. It cannot be doubted that those patterns have a selective advantage (Hecht and Marien, 1956:352), as did the common behaviors of rattlesnakes and bullsnakes when they evolved (and as they may still have), but the advantage in each case may lie not in the resemblances per se but in convergent approaches to common selection pressures. In the case of coral snakes, this hypothesis assumes that the snakes involved are genetically programmed to exploit xanthophore-erythrophore hypertrophy in the course of evolution of disruptive variations of color intensity as a means of effecting concealing coloration. The assumption is not radical, for it is evident that intraspecific color-pattern variants among snakes tend to be channelized and not widely haphazard; in some genera, for example, stripes are the common variant from large median blothces (e.g., *Elaphe*, *Pituophis*), whereas in others transverse bars of varied hue (black, red, yellow) are common variants (e.g., *Sonora*, *Chionactis*). Grobman's (1978) concept of pseudomimicry is consonant with the hypothesis of genetic programming that makes readily available certain sorts of pattern-change in the course of evolution of convergently adaptive pattern and color similarities not related *inter se* but to extraneous factors.

In explanation of the descriptive instead of eponymic terminology adopted here—"deceptive" and "reinforcement" in lieu of "Batesian" and "Müllerian" respectively—we disclaim objection to eponyms categorically, but recognize by personal and pedagogical experience over many years that these particular eponyms do not lend themselves readily to mnemonics, hence are vastly annoying in application. The descriptive terms we have adopted are, on the contrary, self-explanatory as well as equivalent to the eponyms. Batesian mimicry *is* deceptive mimicry, in the sense of a deceiving resemblance of an innocuous species to a harmful one; and Müllerian mimicry *is* reinforcement mimicry in the sense of convergent similarity of harmful species. We propose that these descriptive terms merit acceptance on an equal footing with their long-established eponymic synonyms.

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## REFERENCES

Armstrong, Barry L., and James B. Murphy. 1979. The natural history of Mexican rattlesnakes. Univ. Kansas Mus. Nat. Hist. Spec. Publ. 5:i–vii, 1–88, figs. 1–43, map.

Duellman, William E. 1960. A taxonomic study of the Middle American snake, *Pituophis deppei*. Univ. Kansas Publs. Mus. Nat. Hist. 10(10):599–610, fig. 1, pl. 1.

Gans, Carl, and M. Latifi. 1973. Another case of presumptive mimicry in snakes. Copeia 1973:801–802.

Greene, Harry W. 1979. Behavioral convergence in defensive displays of snakes. Experientia 35:747–748, fig. 1.

Grobman, Arnold B. 1978. An alternative solution to the coral snake mimic problem (Reptilia, Serpentes, Elapidae). J. Herpet. 12(1):1–11, fig. 1.

Hecht, Max K., and D. Marien. 1956. The coral snake mimic problem: a reinterpretation. J. Morph. 98:335–365.

Klauber, Laurence M. 1972. Rattlesnakes: their habits, life histories and influence on mankind. Berkeley and Los Angeles, Univ. California Press. 2 vols.

Kroon, Charles. 1975. A possible Müllerian mimetic complex among snakes. Copeia 1975:425–428.

Leopold, A. S. 1950. Vegetation zones of Mexico. Ecology 31(4):507–518.

Minton, Sherman, A., Jr., and Madge R. Minton. 1969. Venomous reptiles. New York, Scribner's. xii, 275 pp. ill.

MacGregor, John R. 1980. The pattern of the scarlet kingsnake—another viewpoint. Ky. Herpetologist 8(1):1–3.

Orr, Penelope. 1979. The coral snake mimic problem: Pandora's box or just another can of worms? J. Northern Ohio Assoc. Herpetologists 5(1):13–31.

Wickler, Wolfgang. 1968. Mimicry in plants and animals. New York, McGraw-Hill. 253 pp., ill.

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# Historical Biogeography of the Pronghorn in Kansas

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ABSTRACT

The distribution and abundance of pronghorn in Kansas declined precipitously after settlement of the central Great Plains in the late 1800's. The species probably never was completely extirpated in western counties because small herds wandered back and forth between Kansas and adjacent states. The Fish and Game Commission has been successful in reestablishing the pronghorn in western Kansas, and the species eventually might reoccupy much of its former range in the state.

The pronghorn, *Antilocapra americana*, is a characteristic inhabitant of the Great Plains and other non-forested regions of western North America. Its abundance in Kansas was noted by early explorers and settlers, many of whom used the pronghorn as a supplemental source of meat. The species was nearly extirpated in the state when the Kansas Fish and Game Commission initiated a program designed to reintroduce the pronghorn in selected regions it once occupied. Cockrum (1952) briefly summarized the history of the decline in numbers of pronghorn in Kansas prior to reintroduction. The purposes of this paper are to review the historical biogeography of the species in Kansas and to summarize the efforts of the Commission to reestablish populations of pronghorn in the state.

Probably the first written record of pronghorn in the state was by the Spanish explorer Coronado when, in 1540, he wrote of "ciervos, remendados de blanco" (stags patched with white) as he crossed the plains of what eventually would become Kansas (Brennan, 1932). Likewise, when (in 1806) Pike passed through what are now Anderson, Lyon, and Chase counties, he noted that antelope were common (Pike, 1810). An early trapper

in Kansas, J. R. Mead, reported (1899) that, in 1859, "Antelope were abundant everywhere, in summer, migrating south in winter to the Staked Plains." Knox (1875) said that antelope were present "in great numbers on the western plains, in herds of ten or twenty."

J. A. Allen (1874) might have been the first to document a decline in distribution and numbers of pronghorn in Kansas when he observed that, in 1871, pronghorn were "Common in summer as far east as the middle of the state, and formerly ranged much further [*sic*] eastward. Not observed in winter much to the eastward of the Colorado boundary . . . . Although tolerably frequent in northwestern Kansas in summer, they are far less numerous here than in eastern Colorado, or on the plains of southern Wyoming." Records kept at the Fort Hays Military Reservation suggested that pronghorn were declining in numbers in central Kansas by 1877 (Choate and Fleharty, 1975); the annual report for that year noted that "The antelope still lingers on the hills hereabout, but in diminished numbers; whether his stay is due to the peculiarity of his habits or to the fact that he eludes his pursuers more easily than the Buffalo, I do not know." Baker (1889) noted that near WaKeeney, Trego County, pronghorn were "Still comparatively common; and until quite recently, very numerous."

The population of pronghorn in western Kansas declined rapidly thereafter. Lantz (1905a) wrote that pronghorn were "Fast disappearing. A recent law protects these animals, but the law is ignored by many of the settlers in western Kansas. A few small herds have been reported to me within the last year as occurring in the extreme western counties of the state." Lantz (1905b) added that "There seems to be little hope that the antelope will not become completely extinct . . . [in Kansas] within a decade." By 1912 the only report of pronghorn in the state was by C. D. Bunker, who saw three in Stanton County (Kellogg, 1915).

In subsequent years pronghorn were extremely rare in western counties although small herds periodically were seen. In a letter dated 2 July 1924, Hal G. Evarts of Hutchinson wrote that he had received reliable information that, in 1916, a herd of 62 pronghorn was ranging about 25 miles northwest of Cimarron, in the Pawnee Creek breaks in southwestern Kansas. In 1918 he saw seven animals which wintered within one mile of the town of Cimarron, Gray County, and in 1921 a band of 16 spent the summer and winter about 15 miles south and west of Garden City (Nelson, 1925). Carter (1939) indicated that pronghorn remained in Stevens County as late as 1920.

A census conducted by Nelson (1925) revealed that, in 1923, only one band (estimated to contain eight animals) remained in Kansas (in Morton County). However, Carter (1939) referred to a letter from Mr. Bill Mull of Ashland, Clark County, who reported that a herd of seven pronghorn spent the winter on his farm in 1926, and asserted that pronghorn were seen in Wallace County as late as 1929. Moreover, in April of 1931 T. E. Gruver

saw a pair of pronghorn in Hamilton County, south of Syracuse, and others said they had seen as many as four or five in that vicinity (Brennan, 1932).

Hibbard (1933) asserted that the species had been extirpated in Kansas, and Cockrum (1952) reiterated this opinion. We suspect, however, that small herds of pronghorn wandered back and forth from Colorado and Oklahoma and occurred periodically in western and southwestern counties of Kansas. Hall (1955) reported that Mr. August Lalouette of Marion County introduced one young pronghorn from Montana in 1953 and 13 more from that state in 1954. The subsequent history of those animals is unknown.

Pronghorn generally were neglected in Kansas until July of 1962, when a survey by the Kansas Fish and Game Commission revealed the presence of 37 pronghorn in Wallace and Sherman counties. These animals were scattered in small groups and, because most of the males were concentrated in one area, their potential for reproduction was judged to be low (Moore et al., 1962). Therefore, in 1963, plans were made to supplement these animals with a small herd introduced from outside Kansas. On 26 November 1964, 84 animals were transported from Montana and released in Wallace and Sherman counties. At least 13 of these died during or soon after their release (Moore et al., 1964). In January of 1966, 61 pronghorn from Colorado were released in Barber County and eight were sent to the Maxwell Game Refuge in McPherson County. In 1967, 50 pronghorn from Nebraska were released in Ellsworth County; these animals previously had been confined and became separated after their release, thus resulting in a non-reproductive population. Thirty-three pronghorn from Nebraska also were released in Edwards County, and two adult does dispersed as far as 90 miles from the site of release (Coleman et al., 1968).

By 1969 no pronghorn remained in Edwards County, only 15 head remained in Ellsworth County, and the population in Barber County showed no evidence of growth. The only introduction that had proven successful was that in Wallace and Sherman counties. The population in those counties increased at an annual rate of 17 percent through 1969. During 1967, the population increased by 67 head to a total of 211 (Gasswint et al., 1971). By January of 1973 the population had reached 531, and had increased at an annual rate of 20 percent since 1969 (Montei and Hlavachick, 1974). On 29 January 1975, a census of pronghorn populations in Wallace and Sherman counties and adjacent Logan County (the last became inhabited by pronghorn that dispersed eastward from the other two counties) revealed 673 animals, a 27 percent increase over the count made in 1973. A count in Barber and surrounding counties that same year revealed 54 pronghorn, 12 of which had dispersed into Comanche County (Queal et al., 1975).

The increased numbers in Wallace, Sherman, and Logan counties were in spite of the first controlled hunting season for pronghorn in Kansas, which was held in September of 1974. Now, regulated hunting is used annually as

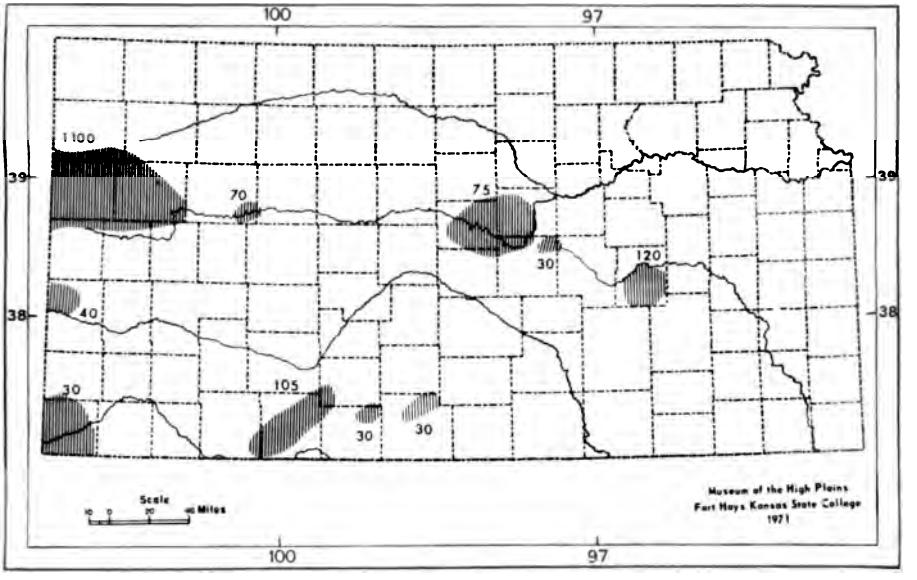


Fig. 1. Map of Kansas showing distribution and abundance of pronghorn in Kansas in December of 1979.

a tool for management of that population. Numbers of pronghorn in westernmost Kansas were monitored continuously by the Fish and Game Commission from the time of the release in 1964 until the winter of 1978, when 845 animals were counted (Funk, 1979a).

Plans were made in 1977 for another transplant of pronghorn from Wyoming. In January of 1978, 63 animals were released in Clark County and 37 in Chase County. Those releases increased the population of pronghorn statewide to between 1200 and 1300 head (Funk, 1978). Other introductions were made in January of 1979, when 98 pronghorn were released in Chase County, 75 in Ellsworth County, 74 in Clark County, 37 in Morton County, and 68 in Gove County. These introductions increased the population of pronghorn in Kansas to its greatest number since the beginning of the Twentieth Century (Funk, 1979b).

The latest introductions were made in an attempt to unite the existing herds in the state. It was anticipated that, if these new herds were as successful as those in Wallace, Sherman, and Logan counties, the distributions of the isolated populations soon would come into contact and gene flow among them would be reestablished. Whether or not this will result where much of the prairie has been put to the plow remains to be seen, but analysis of the diet of pronghorn in western Kansas (Sexson et al., 1980) revealed that dietary requirements of pronghorn are satisfied in a patchwork envi-

ronment of rangeland and cultivated crops such as exists over much of the western half of Kansas. The current (December 1979) distribution and abundance of pronghorn in Kansas are illustrated in Fig. 1.

## Literature Cited


Allen, J. A. 1874. Notes on the mammals of portions of Kansas, Colorado, Wyoming and Utah. Part I. On the mammals of middle and western Kansas. Bull. Essex Inst. 6:43–52.

Baker, A. B. 1889. Mammals of western Kansas. Trans. Kansas Acad. Sci. 11:56–58.

Brennan, L. A. 1932. Mammal extinction in Kansas. I. The pronghorned antelope. Aerend 1932:231–236.

Carter, F. L. 1939. A history of the changes in population of certain mammals in western Kansas. Unpubl. M.S. thesis, Fort Hays Kansas State College, vi + 1–78.

Choate, J. R., and E. D. Fleharty. 1975. Synopsis of native, Recent mammals of Ellis County, Kansas. Occas. Papers Mus., Texas Tech Univ. 37:1–80.

Cockrum, E. L. 1952. Mammals of Kansas. Univ. Kansas Publ., Mus. Nat. Hist. 7:1–303.

Coleman, D. C., W. C. Peabody, G. J. Gasswint, and B. D. Hlavachick. 1968. Movements and population trends of antelope. Job Progress Report, pp. 65–69, Kansas Forestry, Fish and Game Commission, Pratt, Kansas.

Funk, T. 1978. Antelope distribution narrative. Kansas Fish and Game Commission report, Pratt, Kansas. 2 pp.

Funk, T. 1979a. Antelope population trends. Unit Report, Kansas Fish and Game Commission, Pratt, Kansas. 2 pp.

Funk, T. 1979b. Antelope trapping report. Kansas Fish and Game Commission, Pratt, Kansas. 2 pp.

Gasswint, O. J., W. C. Peabody, L. M. Queal, and B. D. Hlavachick. 1971. Movements and population trends of antelope. Job Progress Report, pp. 1–70, Federal Aid Project W-23-R-9, Kansas Forestry, Fish and Game Commission, Pratt, Kansas.

Hall, E. R. 1955. Handbook of mammals of Kansas. Misc. Publ. Mus. Nat. Hist., Univ. Kansas 7:1–303.

Hibbard, C. W. 1933. A revised check list of Kansas mammals. Trans. Kansas Acad. Sci. 36:230–249.

Kellogg, R. 1915. The mammals of Kansas . . . . Unpubl. M.A. thesis, Univ. Kansas, 241 pp.

Knox, M. V. B. 1875. Kansas Mammalia. Trans. Kansas Acad. Sci. 4:19–22.

Lantz, D. E. 1905a. A list of Kansas mammals. Trans. Kansas Acad. Sci. 19:171–178.

Lantz, D. E. 1905b. Kansas mammals in their relations to agriculture. Kansas State Exp. Sta. Bull. 129:331–404.

Mead, J. R. 1899. Some natural history notes of 1859. Trans. Kansas Acad. Sci. 16:280–281.

Montei, K., and B. D. Hlavachick. 1974. Format for Kansas' first antelope season. Proc. Sixth Antelope States Workshop, pp. 142–152.

Moore, G. C., D. C. Coleman, A. Schultz, O. J. Gasswint, and B. D. Hlavachick. 1962. Distribution of antelope. Job Completion Report, Federal Aid Project W-23-R-1. Kansas Forestry, Fish and Game Commission, Pratt, Kansas. 5 pp.

Moore, G. C., D. C. Coleman, A. Schultz, O. J. Gasswint, and B. D. Hlavachick. 1964. Distribution of antelope. Job Completion Report, Federal Aid Project W-23-R-5. Kansas Forestry, Fish and Game Commission, Pratt, Kansas.

Nelson, E. W. 1925. Status of the pronghorned antelope, 1922–1924. U.S. Dept. Agric. Bull. 1346:1–64.

Pike, Major Z. M. 1810. Account of an expedition to the sources of the Mississippi and through the western parts of Louisiana, to the sources of the Arkansaw, Kansas, LaPlatte and Pierre Jaune rivers; performed by order of the government of the United

States during the years 1805, 1806, and 1807. And a tour through the interior parts of New Spain, when conducted through these provinces by order of the captain general, in the year 1807. C. and A. Conrad and Co., Philadelphia. Microcard, no pagination.

Queal, L. M., W. C. Peabody, J. A. Norman, and K. Montei. 1975. Movements and population trends of antelope. Job Progress Report, pp. 71–75, Kansas Forestry, Fish and Game Commission, Pratt, Kansas.

Sexson, M. L., J. R. Choate, and R. A. Nicholson. 1980. Diet of pronghorn in western Kansas. J. Range Manage., in press.

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# The Effect of *Sigmodon hispidus* on Summer Diel Activity Patterns of *Microtus ochrogaster* in Kansas

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ABSTRACT

Activity periods of *Microtus* and *Sigmodon* were monitored by checking live-traps for 12 consecutive 2-hour intervals. *Sigmodon* were active nocturnally with peaks of activity at dawn and dusk. Where no *Sigmodon* were captured, *Microtus* also showed activity patterns with dawn and dusk peaks. Where *Sigmodon* and *Microtus* were both captured, *Microtus* activity was more evenly distributed throughout the night.

Several recent papers exploring the relationships between *Sigmodon hispidus* and *Microtus ochrogaster* (Terman, 1974, 1978; Glass and Slade, 1980) or *M. pennsylvanicus* (Terman and Johnson, 1971) have demonstrated that *Sigmodon* aggressively inhibit *Microtus* activities in the laboratory and appear to do so in the field. Glass and Slade (1980) found that the degree of spatial and temporal segregation of *S. hispidus* and *M. ochrogaster* varied seasonally and that spatial rather than temporal segregation was the predominant pattern in the summer. They suggested that temporal segregation would have been sufficient for *Microtus* to avoid *Sigmodon* aggression, but that hot summer temperatures restricted *Microtus* activities to nocturnal periods when *Sigmodon* were also active. However, Glass and Slade could only identify captures as dirunal or nocturnal, so they could not detect temporal separaation within the nocturnal period in the field. Under normal summer temperature regimes in the laboratory, they reported a tendency for *Microtus* to shift its nocturnal activity away from those hours of highest *Sigmodon* activity. This paper reports a more complete field study of the impact of *Sigmodon* presence on *Microtus* summer diel activity patterns.

Two previously established trapping grids on the Nelson Environmental Studies Area, 14.5 km northeast of Lawrence, Kansas, were live-trapped from 13 June to 2 August 1978. They were selected so that grid 1 supported both *Microtus* and *Sigmodon* populations, whereas grid 2 had *Microtus* only. Grid 1 was 7 stations by 6 stations with 15 m between stations, and

was located in an abandoned field overgrown with asters (*Aster multiflorus*), sunflowers (*Helianthus* spp.), goldenrod (*Solidago* sp.) and several other weedy perennials and annuals. One collapsible Sherman (23 cm × 9 cm × 8 cm) and one modified Fitch (Rose, 1973) live trap were set at each station. From 7 to 17 ($\bar{x}$ = 11; 11.6/ha) individual *Sigmodon hispidus* and from 34 to 46 ($\bar{x}$ = 39; 41.3/ha) *Microtus ochrogaster* were captured during each of 4 trapping sessions, resulting in a total of 58 and 258 captures, respectively. Grid 2 was 8 × 12 with 7.5 m between stations, and was located approximately 1 km northwest of grid 1 in an old hayfield dominated by cultivated brome (*Bromus inermis*) and little bluestem (*Andropogon scoparius*), grading into dogwood (*Cornus drummondii*), Osage orange (*Maclura pomifera*), and cottonwood (*Populus deltoides*) along an intermittent stream. One collapsible Sherman trap was set per station. From 12 to 23 ($\bar{x}$ = 16; 30.1/ha) *Microtus* were captured per trapping session, for a total of 74 captures, but the only *Sigmodon* captured was an adult female caught once. Traps were checked every two hours for one 24-hour period each week, alternating weeks between grids. At each capture the species, age, sex, weight and time of capture (military central daylight time) were recorded. Even though most individuals were toe-clipped or ear-tagged, individual activity profiles could not be constructed because few animals were captured more than twice in a 24-hour period.

The activity patterns of *Microtus* and *Sigmodon*, as indicated by time of capture, are similar to each other (Fig. 1) and to those reported by Calhoun (1945). Both species show bimodal frequencies of capture with evening and morning peaks. The principal alteration in *Microtus* activity on grid 1 was a third peak, perhaps better described as sustained activity, in the middle of the night. (Glass and Slade (1980) also found an increase in *Microtus* activity from 2400–0800 hours in the presence of *Sigmodon* in the laboratory, but they did not observe much activity earlier in the night.) Chi-square tests of independence were used to test for statistically significant differences in these patterns. The captures from 1200–1800 hours were combined in the analysis to insure expected values near 5 for each cell. The differences in activity patterns between *Sigmodon* on grid 1 and *Microtus* on grid 2 were of only marginal significance ($\chi^2_7 = 12.24$, $0.05 < P < 0.10$; 2400 and 200 hours were combined) with the largest differences occurring in relative height and timing of the morning peak. *Microtus* activity patterns on grid 1 and grid 2 were significantly different ($\chi^2_8 = 18.46$, $0.01 < P < 0.025$), the principal difference being the aforementioned activity in the middle of the night.

Glass and Slade (1980) suggested that high summer temperatures restricted periods of *Microtus* activity so we divided our *Microtus* captures into those from cool, necessarily moist days (maximum temperatures 23.3–28.3°C, minimum temperatures 16.1–18.3°C, 7.4–38.6 mm of rainfall) and

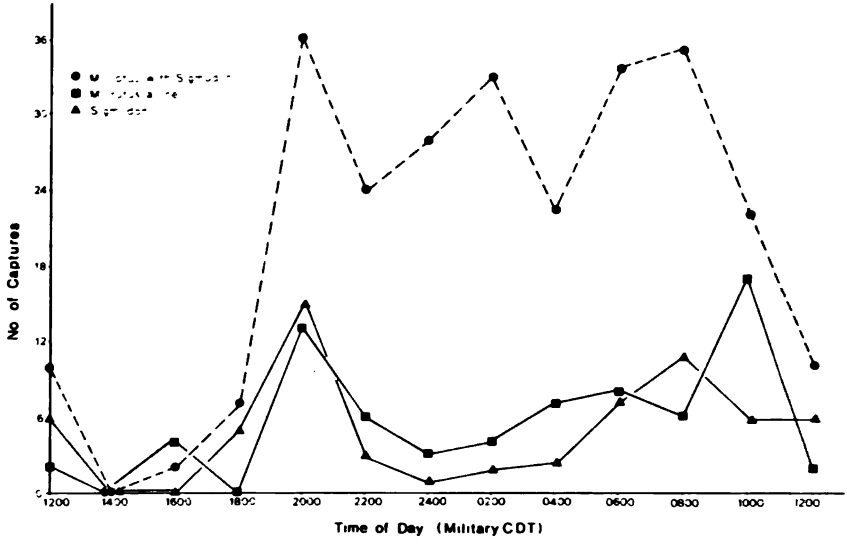


Fig. 1. *Microtus* activity in the presence and absence of *Sigmodon* compared to activity of *Sigmodon*.

hot, dry days (max. temp. 28.3–37.2°C, min. temp. 17.2–25.0°C, 0.0–3.3 mm of rainfall). There were no significant differences ($\chi^2_8 = 9.15$, $0.10 < P < 0.50$) between activity patterns on hot and cool days for both grids combined; we also tested for possible differences on each grid separately since they had not been trapped on the same days and differences due to *Sigmodon* presence were partially confounded with weather. On grid 1 no significant differences were found ($\chi^2_8 = 4.10$, $0.50 < P < 0.90$); on grid 2 there was a marginal tendency for activity to continue later in the morning on cool days with morning rain ($\chi^2_8 = 14.28$, $0.05 < P < 0.10$). These data do not refute the hypothesis of temperature effects on *Microtus* activity periods because even the "cool" days may have been quite warm and humid for voles. However, our data suggest that if summer temperatures restrict *Microtus* activity, there is little response to day to day fluctuations in temperature. More pronounced, e.g., seasonal, changes in temperature regime would be required to rigorously test for temperature effects.

We also checked for possible age (weight class) and sex differences in time of capture for both *Sigmodon* and *Microtus* and found no differences ($P > 0.10$ for all tests).

This experiment was designed to test specifically for *Microtus* activity pattern shifts in the presence of *Sigmodon*. However, there were other differences between grids 1 and 2 which deserve mention. The grids differed in size, trap dispersion and density, and vegetation type, though both grids

were in old fields. However, we know of no reason nor any published papers which suggest that any of these differences would modify observed activity patterns.

Calhoun (1945) observed that, at high population densities, subordinate *Sigmodon* shifted activity periods away from peak times so that observed activity period for populations might vary with population density. Grid 1 supported more dense *Microtus* populations as measured by individuals captured, than did grid 2 (41/ha versus 30/ha). However, number captured was variable enough between trapping periods (pooled $S^2 = 64.4$) that this difference was not statistically significant ($t_6 = 0.72$, $0.4 < P < 0.5$). Furthermore, voles were captured at 37 of 42 stations on grid 1, but only 43 of 96 stations on grid 2. The more diverse habitat of grid 2 resulted in only ½–⅔ of the grid actually being suitable for voles (Bruce Carnes, pers. comm.) so that effective densities were at least as high on grid 2 as on grid 1. Thus, activity shifts toward the middle of the night by *Microtus* on grid 1 could not be attributed simply to an increase in population density.

In conclusion, at the latitude of Lawrence, Kansas, *Sigmodon* and *Microtus* have become syntopic only recently (Genoways and Schlitter, 1967; Glass and Slade, 1980), and the nature of their interaction probably has not stabilized. At present, their interactions seem to depend on physical contact with *Sigmodon* being aggressively dominant (Terman, 1974; Glass and Slade, 1980). Thus, temporal avoidance would be as effective as spatial avoidance in reducing the effect of *Sigmodon* on *Microtus*. However, given the summertime temperatures of Kansas, only moderate changes in *Microtus* activity periods seem possible. *Microtus* respond to *Sigmodon* presence by increasing their activity during the middle of the night when *Sigmodon* are less active (or alternatively, by curtailing activities at dawn and dusk when *Sigmodon* are most active), but still show strong temporal overlap with *Sigmodon*.

## Acknowledgments

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## Literature Cited

Calhoun, J. B. 1945. Diel activity rhythms of the rodents, *Microtus ochrogaster* and *Sigmodon hispidus hispidus*. Ecology 26:251–273.

Genoways, H. H., and D. A. Schlitter. 1967. Northward dispersal of the hispid cotton rat in Nebraska and Missouri. Trans. Kansas Acad. Sci. 70:505–518.

Glass, G. E., and N. A. Slade. 1980. The effect of *Sigmodon hispidus* on spatial and temporal activity of *Microtus ochrogaster*: Evidence for competition. Ecology 61:358–370.

Rose, R. K. 1973. A small mammal live trap. Trans. Kansas Acad. Sci. 74:14–17.

Terman, M. R. 1974. Behavioral interactions between *Microtus* and *Sigmodon*: A model for competitive exclusion. J. Mamm. 55:705–719.

Terman, M. R. 1978. Population dynamics of *Microtus* and *Sigmodon* in central Kansas. Trans. Kansas Acad. Sci. 81:337–351.

Terman, M. R., and D. I. Johnson. 1971. The effects of *Sigmodon hispidus* on *Microtus pennsylvanicus* in a confined area. Trans. Kansas Acad. Sci. 74:217–220.

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# Kansas Academy of Science Abstracts Of Contributed Papers 113th Annual Meeting, Southwestern College Winfield, Kansas, 20 March 1981

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SOME ASPECTS OF THE ECOLOGY OF THE SAN SALVADOR ROCK IGUANA, *CYCLURA RILEYI*. Robert F. Clarke, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

Small populations of the large "rock iguana," an endangered species, occur on San Salvador and its cays in the eastern Bahamas. Its habitat and agonistic behavior are illustrated. Territorial declaration is actual attack, which differs from the more usual ritualized displays of other iguanid species. A comparison is shown using motion pictures.

BREEDING ECOLOGY OF THE LEAST TERN IN KANSAS. Margaret B. Schulenberg, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

Nesting populations of the Interior Least Tern (*Sterna albifrons athalassos*) in Kansas were censused and habitat, as well as other aspects of the breeding biology, were described during the summer of 1980. Alkali salt flats and sandbars of shallow river bottoms, principally in the central and southern portions of the state, were the preferred habitats. Approximately 55 pairs of nesting terns were recorded in seven colonies; five of these colonies had not been recorded previously. Nesting activity began on 29 May and continued through 26 July. Nesting success was judged to be good. The July population contained 232 adults and 78 fledged juveniles.

OBSERVATIONS ON THE FILAMENTOUS ALGAE OF THE ARKANSAS RIVER IN KANSAS. Danny C. Reinke, State Biological Survey of Kansas, 2045 Avenue A., Campus West, Lawrence, Kansas 66044.

During the summer of 1980 the full length of the Arkansas River in Kansas was sampled for filamentous algae. Three species, *Enteromorpha prolifera* (Muell.) Ag. subsp. *prolifera, Hydrodictyon reticulatum* (L.) Lagerh. and *Cladophora glomerata* (L.) Kuetz. were found to dominate the algal flora. *Cladophora* was abundant in the upper Arkansas and found in all samples in small amounts. *Hydrodictyon* was found in trace amounts in the upper Arkansas and was the most abundant species near Great Bend, but was rare or absent in the lower regions beyond Sterling. *Enteromorpha* was rare or absent above Ellinwood, but constituted the dominant species below. Members of the Oedogoniales, Ulotrichales, Zygnematales and Hormogonales

were also collected, but were never as abundant as the three dominant species.

MERICARP VARIATIONS OF *HARBOURIA TRACHYPLEURA* ALONG AN ELEVATIONAL GRADIENT. Marc D. Linton, Logan Junior High, Topeka, Kansas 66608.

Three populations of *Harbouria trachypleura* (Gray) (Umbelliferae) lying along an elevational transect on the Front Range of the Rocky Mountains in Colorado were studied to determine differences in their mean mericarp (single-seed) number, weight, and abortion. Plants at the highest elevation site produced more, but smaller, mericarps than plants at the lower sites, and there was considerable inefficiency in mericarpal development. This indicates that high elevation plants may be adapted to less predictable growing seasons by producing many, but smaller parts such that few resources are lost in the event of abortion due to seasonal resource depletion. Regressions of mericarp number, weights, or development to vegetative plant parts usually were not significant. This indicates that possibly concurrent or non-root stored resources were not influencing mericarp development. Abiotic factors were probably determining mericarpal characteristics: unpredictable and scarce moisture was important to plants at the lowest elevation while the length of the growing season was unpredictable for plants at the highest elevation.

SCREENING STUDY ON THE EFFECTS OF VESICULAR-ARBUSCULAR (VA) MYCORRHIZAL FORMING FUNGI ON BLACK WALNUT SEEDLINGS. M. W. Melichar, Forestry Department, Kansas State University, Manhattan, Kansas 66506, H. E. Garrett, and G. S. Cox, Forestry Department, University of Missouri-Columbia, Columbia, Missouri 65202.

The effects of VA mycorrhizal forming fungi on the growth and development of black walnut (*Juglans nigra* L.) were studied. Seedlings were inoculated with relatively pure isolates and/or combinations of *Glomus caledonius, Glomus fasciculatus, Glomus etunicatus, Glomus microcarpus* and *Glomus mosseae* and compared to non-inoculated controls. All plants were grown in the greenhouse for 198 days, lifted and evaluated. Percent infection, root dry weight, total root length, number of lateral roots, stem dry weight, stem diameter, stem height, leaf area, total seedling dry weight and root/shoot ratio were determined for each seedling. Seedlings inoculated with *Glomus microcarpus, Glomus microcarpus+Glomus fasciculatus*, and *Glomus microcarpus+Glomus etunicatus+Glomus fasciculatus* demonstrated superior growth and development to inoculation with other species and non-inoculated controls.

COMPUTING THE EXPONENTIAL OF COMPARTMENTAL MATRICES. Gary Lee McGrath, Department of Mathematics, Pittsburg State University, Pittsburg, Kansas 66762.

Identification algorithms for the linear analysis of compartmental ecosystems requires computing the partial derivatives of the exponential matrix numerically. The exponential matrix is approximated by a Pade expansion. The identification problem is formulated as a constrained optimization problem. Numerical results and computer programs will be presented.

CHEMICAL VARIATIONS OF A STORM RUNOFF EVENT IN THE KONZA PRAIRIE. Donald O. Whittemore, Truman C. Waugh, and O. Karmie Galle, Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66044, and G. Richard Marzolf, Division of Biology, Kansas State University, Manhattan, Kansas 66506.

Stream baseflow is sustained by groundwater from several limestone units in watersheds of the Konza Prairie, a research natural area in the northern Flint Hills, Kansas. In 1980, the first substantial runoff that occurred after a late April burning of a 490 hectare watershed came on June 4. Concentration ranges of solutes in stream waters collected from the watershed exit during the 2½ hours of maximum storm runoff (greater than 170 l/sec flows), were 48–80 mg/l Ca, 10.0–18.6 mg/l Mg, 4.4–7.2 mg/l Na, 1.4–2.6 mg/l K, 0.6–1.0 mg/l Sr, 167–280 mg/l $HCO_3$, 24–44 mg/l $SO_4$, 3.2–4.4 mg/l Cl, 0.5–2.3 mg/l $NO_3$, 0.04–0.49 mg/l $PO_4$, and 12.8–13.9 mg/l $SiO_2$. Solute contents in the runoff varied principally in two ways. Concentrations of constituents contributed mainly from groundwater inflow, Ca, Mg, Na, Sr, $HCO_3$, and $SO_4$, first increased slightly, then fell markedly as overland flow diluted the stream waters, and finally slowly rose during stream recession. Specific conductance showed the same pattern, falling from 508 to 310 $\mu$mho/cm, suggesting that most of the dissolved solids came from a groundwater source. The initial increase in the solutes probably represents flushing of groundwater inflow stored in upstream channels, alluvium, and colluvium, and soluble salts accumulated in unsaturated alluvium and colluvium by evapotranspiration of groundwater. Concentrations of colloidal and dissolved organic matter and the dissolved nutrients K, $NO_3$, and $PO_4$ greatly increased in the storm runoff, then decreased slowly during stream recession. This indicated that these constituents were leached mainly from soils by overland flow. Chloride contents were low and decreased only slightly during the storm, implying that a soil source was important relative to the small groundwater input. Both maximum concentrations of soil derived and minimum concentrations of groundwater contributed solutes in the runoff occurred about 1½ hours after peak flow. Mass solute flows (maxima during the storm to baseflow values 9 days later), ranged from 14,000–340 g/min

for $HCO_3$ to 57–0.1 g/min for $NO_3$ and 10–0.05 g/min for $PO_4$. Maximum rates of dissolved nutrient erosion by overland flow computed for the total watershed area were 0.15, 0.12, and 0.021 g/ha·min for K, $NO_3$, and $PO_4$, respectively.

A PESTICIDE EVALUATION PLOT TECHNIQUE. Jerry L. Condray and Salvatore S. Attanasio, Weed and Pesticide Division, Kansas State Board of Agriculture, Topeka, Kansas 66612.

The need for a pesticide field plot technique to maximize information from limited land area is especially important when working with perennial weed infestations. Comparison of rates and pesticides is obtainable using line transect sampling with less investment than with discrete rate or linear logarithmic field plots. Provision may be included for untreated check areas within the plots. Advantages include simplicity of field marking of plots and adaptability for granular application. The technique enables efficient rate comparisons and can provide indication of potential efficacy of two and three pesticides in combinations. Precise measurement of pesticide combination specific rates is difficult in the overlapped areas of the circular plots.

ENTEROMORPHA (ULVALES, CHLOROPHYCEAE) IN KANSAS. Danny C. Reinke, State Biological Survey, 2045 Avenue A., Campus West, Lawrence, Kansas 66044.

Field work by the State Biological Survey has added 16 additional collection sites for *Enteromorpha prolifera* (Muell.) Ag. subsp. *prolifera* in Kansas and supports the suggestion that *Enteromorpha* is more common than would be indicated by the algal literature. *Enteromorpha* is primarily a marine genus but has been occasionally reported from inland salt springs and some inland lakes. In contrast to marine species, the mature thalli of most freshwater species consist of long, usually branched, hollow tubes with a wall one cell in thickness. Recent reports of *Enteromorpha* from Oklahoma exemplify that the inland distribution is poorly known.

FIRST RECORD OF *CORDYLOPHORA LACUSTRIS* ALLMAN FROM KANSAS. John D. Ransom, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

*Cordylophora lacustris* Allman, a unique colonial hydroid coelenterate usually abundant in brackish waters, was collected from Melvern Lake, Osage County, Kansas, on 14 September and 3 October 1980. Those collections constitute a first record for Kansas.

UNIONACEAN MUSSELS OF THE CHIKASKIA RIVER BASIN. Victor P. Claassen and Donald A. Distler, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208.

Sixteen species of Unionacean Mussels were reported from the Chikaskia River in the early 1900's. At present nine of the 16 species are represented by live individuals and five species by fresh valves. Of the two remaining, *Tritigonia verrucosa* is represented by a few weathered valves and no evidence of *Truncilla truncata* has been found. *Obliquaria reflexa*, unreported in earlier surveys, is represented by a single weathered valve. *Quadrula pustulosa*, *Quadrula quadrula*, and *Leptodea fragilis* comprise 84 percent of the valve material. The remaining 16 percent is represented by living or fresh material of 11 species. The decline in the diversity of mussels in the Chikaskia River Basin may be attributed largely to anthropogenic practices of the past 80 years. Planned innundation of the mainstream near Corbin, Kansas will have severe impact on the Unionacean fauna by drastically reducing flow in the lower one-third of the basin where the greatest diversity of mussels occurs.

ANNUAL CYCLES OF CONGENERIC CALANOIDS IN LAKE READING, KANSAS. Carl W. Prophet, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

The zooplankton fauna of Lake Reading is dominated by two calanoid copepods, *Diaptomus siciloides* and *D. pallidus*. Preliminary data indicate temporal separation of peak populations resulting from different reproductive seasons is an important resource partitioning mechanism for these two species.

THE EFFECTS OF CHRONIC ALCOHOL INJECTIONS ON AGGRESSIVE RESPONDING IN RATS MAINTAINED ON A SEMIDEPRIVATION DIET. James L. Tramill, Department of Instructional Services, Wichita State University, Wichita, Kansas 67208, and Stephen F. Davis, Department of Psychology, Emporia State University, Emporia, Kansas 66801.

A 2 by 3 factorial design was used to evaluate the effects of type of injection (saline vs. ethanol) and amount injected (.25 cc, .50 cc, .75 cc/100 g body weight) on shock-elicited aggression. All subjects were maintained on a restricted diet for the duration of the experiment. Intraperitoneal injections were administered to all subjects for 15 days. On the 15th day, each subject received shock-elicited aggression testing 15 min after the daily injection. The results indicated that the alcohol-injected subjects were significantly more aggressive than the saline-injected subjects at the .25-cc level, but these subjects were significantly less aggressive at the .75-cc level.

CHANGES IN THE FORCED EXPIRATORY SPIROGRAM IN HIGH SCHOOL SMOKERS. Bruce D. MacBain and Donald H. Richards, St. Mary of the Plains College, St. Joseph Medical Center Campus, Wichita,

Kansas 67218, and C. Dyeanne Racette, Morris A. Hund, and Surendra P. Singh, Kansas Newman College, Wichita, Kansas 67212.

To address the question of whether one could detect spirographic changes in lung function due to cigarette smoking in high school aged children, spirographic data consisting of forced vital capacity (FVC), forced expiratory volume in one second ($FEV_1$), forced expiratory volume after three seconds ($FEV_3$), forced expiratory volume in one second and three seconds as a percentage of the forced vital capacity ($FEV_1\%$, $FEV_3\%$), and the maximum mid expiratory flow rate during the middle half of a forced expiratory volume (MMFR), were obtained from 506 high school student volunteers.

Each student filled out a questionnaire to determine if they smoked, how long they smoked, how often they smoked, and if they suffered from any other pre-existing pulmonary condition that might affect the spirograph. Those with any pre-existing pulmonary conditions, on medication, or non-cooperative with the standardized technique employed were excluded from the study. The remaining 399 subjects were divided into three groups consisting of a nonsmoking control group, a low lifetime total group (less than 6000 cigarettes), and a high lifetime total group (a lifetime total of more than 6000 cigarettes). Computations to ascertain whether altered pulmonary function values, reflecting dose related airing changes between nonsmokers, light smokers, and heavy smokers in high school aged subjects with short smoking histories are at this time in progress.

THE HISTORY AND DEMONSTRATION OF EARLY ELECTROMEDICAL DEVICES. Leland E. Keller, Department of Biology, Pittsburg State University, Pittsburg, Kansas 66762.

The widely publicized frictional electricity and lightning studies of Franklin, the physiological studies of Galvani and the development of the induction coil by Faraday are major historical events which led to the use of electricity in medicine. During the 1700 and 1800's the mysterious force of electricity was viewed and studied with fascination and glamour. The electrical devices designed and used by legitimate researchers or clever charlatans were readily accepted by the public. The public was more impressed with a cure or treatment of disease which could be heard, seen, smelled or felt. The early equipment to accomplish this was a high voltage, high frequency static generator which ionized the air, crackled, produced a blue glow, tingled and warmed the skin. Descendents of this device are the high voltage, high frequency violet ray instruments, electromagneto and induction coil devices. The illustrated presentation covers the early history of electrotherapy, designs of electromedical gadgets, their public and professional acceptance and rejection. A few of the author's extensive collection of electromedical treatment devices will be demonstrated.

PROGNOSTIC INDICATORS OF ULTIMATE LONG-TERM SURVIVAL FOLLOWING ADVANCED LIFE SUPPORT. Michael E. Szczygiel, Emergency Medical Training Program, University of Kansas College of Health Sciences and Hospital, Kansas City, Kansas 66103.

A two year (1978–79) retrospective study of 92 long-term survivors following advanced life support in the field was undertaken. Long-term survivors of advanced life support were divided into two groups: the first survived admission to the intensive care unit, but subsequently died in the hospital, the second survived to ultimate discharge from the hospital. Believing the purpose of life support to be ultimate survival, analysis of these two groups' response to treatment in the field was compared in an attempt to establish prognostic indicators for ultimate long-term survival.

The groups were compared for sex, age, basic and advanced provider response time, scene and transport time, witnessed versus unwitnessed arrest, traumatic versus medical arrest, type of airway, presence of aspiration, initial cardiac rhythms, post arrest vital signs, number of defibrillations, post arrest EKG changes, essential-useful drugs used, and duration of basic and advanced life support.

Of all prognostic indicators studied, duration of advanced life support correlated most closely with ultimate survival. Those patients (N = 21) requiring less than ten minutes of advanced life support had an ultimate survival rate of 86%. Patients (N = 43) requiring ten to twenty minutes of advanced life support had an ultimate survival rate of 53%. Patients (N = 18) requiring twenty to thirty minutes of advanced life support had an ultimate survival rate of 61%. Patients (N = 10) requiring more than thirty minutes of advanced life support had an ultimate survival rate of 10%.

This paper advances the definition of ultimate survival of advanced life support to mean discharge of the patient from the hospital, and advocates this definition as the most objective evaluation of success of advanced life support. The paper furthermore offers duration of advanced life support as an effective prognostic indicator of a patient's chance for ultimate survival.

LUNAR AND ANNUAL VARIATIONS IN CONCENTRATION OF CARDIOACTIVE URINARY METABOLITES IN HUMANS. Harry D. Rounds, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208.

Human and mouse blood, cockroach haemolymph and *Coleus* leaf extracts have been reported to contain cardioacceleratory materials which reach low levels at full moon and new moon. Also reported are high levels of similar activity in insect nervous tissue at corresponding times. It was assumed that the cardioactivity was not released on certain days near to the phases to account for the findings with both haemolymph and nervous tissue.

Subsequently, it was found that human urine contained considerable cardioacceleratory activity. It was assumed that if the cardioactivity present in human urine reflected the lunar phases it would be similar to that found in blood and that some unidentified neuro-endocrine source simply was not releasing the materials. The findings were not as postulated.

Urine cardioacceleratory activity was found to reach highs at the major phases. The main peak during the first half of the year occurred at full moon while a weak secondary peak tended to occur at new moon. After the summer solstice, the peaking reversed. At the winter solstice it reversed again. Cardioacceleratory activity was lowest at the summer solstice and highest at the winter solstice.

PLANT PIGMENT ADAPTATIONS TO FIELD IRRADIANCE CONDITIONS. Craig E. Martin and David M. Titus, Department of Botany, University of Kansas, Lawrence, Kansas 66045.

The validity of assumptions concerning plant pigment adaptations to high and low light regimes was tested in three different field situations. Leaves were collected in the field, immediately frozen, extracted with acetone, and chlorophyll determinations were made on the extracts. In addition, leaf thickness and specific weight (weight/area) were measured. Comparisons were made between five weedy species growing in full sunlight and five forest understory species; outer- and innermost leaves of four tree species; and between individuals of a sunflower species growing in full sunlight and in the forest understory. In the first three situations, the results fit generalizations based on past studies of sun and shade species: sun leaves were typically thicker, had higher specific weights, higher chlorophyll a/b ratios, slightly higher chlorophyll concentrations on an area basis, and lower chlorophyll concentrations on a dry weight basis relative to shade leaves. These generalizations did not hold in the case of the sunflower which grew in both sunny and shady environments. The results of this study indicate that all plants do not adapt to different irradiance regimes in the same manner.

ASPECTS OF SALT AND WATER BALANCE IN THE NOTOSTRACAN, *LEPIDURUS BILOBATUS*. K. Charles Hunter, Southwestern College, Winfield, Kansas 67156.

The tadpole shrimp, *Lepidurus bilobatus* is a poorly described species inhabiting moderately saline lakes in Oregon and Nevada. Mechanisms of ionic and osmotic regulation were investigated. Compared to other freshwater crustaceans permeability to both water and salt is extremely high. The water permeability constant for *L. bilobatus* is 3.2. The sodium influx rate for animals in 1 mM NaCl is 7.0 $\mu$M $g^{-1}$ $hr^{-1}$. The influx rate is not

significantly altered in media with high calcium concentration. The sodium transport mechanism in *L. bilobatus* appears to have a low affinity. The external sodium concentration for half saturation is 13.2 mM. The osmotic concentration of the hemolymph is low compared to other freshwater crustaceans, averaging 132 mOsm $KgH_2O^{-1}$. The urine is only slightly hyposmotic. Urine osmotic concentration averages 112.4 mOsm $KgH_2O^{-1}$ and the urine-hemolymph ratio is 0.85. The osmoregulatory machinery and strategy employed by notostracans and presumably other branchiopods appear to be quite different from that of other freshwater crustaceans. Moreover, there appear to be significant differences in salt balance mechanisms among the Notostraca.

NEAR-ULTRAVIOLET LIGHT RECEPTION IN MALLARDS AND PASSERIFORMES. John Parrish, Ricky Smith, Roger Benjamin and James Ptacek, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

Humans are unable to detect near-ultraviolet (UV) light (300–380 nm), but insects and reptiles, and more recently, pigeons and hummingbirds have been shown to possess UV-light detection capabilities. The present studies show that the primitive duck, as well as several more recently evolved passerine birds also have the ability to see near-UV light. Classical cardiac-conditioning techniques were employed to determine UV sensitivity in six Mallards and one female Belted Kingfisher. Both species of birds exhibited increased cardiac rates during about 90% of the trials, following initial stimulus-shock conditioning to UV light between 340–360 nm. Control trials in which the UV light was blocked by a UV-absorbing filter resulted in positive cardiac responses in less than 6% of the trials. Data from the passerines were obtained using a Skinner box in which postabsorptive birds could obtain a food reward when they pecked at a key during UV light presentation. A male Cardinal, House Sparrow, Brown-headed Cowbird, and an adult Harris' Sparrow all showed 65–80% key-pecking coincidence to UV light (330–360 nm), but only 9–16% coincidence in the presence of the UV-absorbing filter. The present findings that both the relatively primitive Mallard and the more recently evolved passerine species can detect near-UV light imply that most, if not all, avian species may be capable of UV light reception, possibly because birds retained similar retinal structures during their evolution from the UV-sensitive reptiles. The adaptive value of UV-light reception in birds is not known, but it is tempting to suggest its use for location of the sun behind clouds, for orientation to polarized light and for detection of UV patterns on plants and animals, similar to its uses by the UV-sensitive insects. Further research evaluating UV sensitivity among other groups of birds is necessary to support these hypotheses.

A DYNAMIC MODEL FOR THE RESPONSE OF THE *LIMULUS* EYE TO A LIGHT PULSE. Carl S. Helrich, Department of Physics, Bethel College, North Newton, Kansas 67117.

Data from electrophysiological experiments conducted on the horseshoe crab, *Limulus polyphemus*, eye have revealed the existence of two underlying processes in the excitation of the membrane of the visual cell. Evidence for this appears both in the unclamped receptor potential (RP) and the light initiated current (LIC) during a clamped condition. For some time it has been supposed that the origin of these processes is the separate excitation of the microvillar membrane and the cell body membrane respectively. Here a model is presented based on this supposition. The current pulse originates in the microvillar region as a consequence of the rhodopsin dark reaction. It is then postulated that a chemical reaction front moves in time across the cell body exciting the membrane. Hodgkin and Huxley kinetics are assumed for each membrane. Results of computer experiments with this model are presented and compared with actual LIC's. Qualitative agreement has been good which supports the underlying assumptions of the model. The dynamic response has also revealed the importance of exterior volumes as sodium reservoirs. Quantitative disagreement is attributable to differences in the time frame for the kinetics of the *Limulus* eye and that for the giant squid axon used by Hodgkin and Huxley.

STRUCTURE OF ASPARTATE TRANSFER RNA. Vikram N. Vakharia and Ram P. Singhal, Department of Chemistry, Wichita State University, Wichita, Kansas 67208.

We are interested in the study of structure and function of aspartate transfer RNAs (tRNAs) from mammalian sources since this is the only tRNA that changes between normal and tumor cells. We have purified two isoacceptors of this tRNA and also discovered that each isoacceptor separates into two subspecies on further purification. Here were reported the primary structure of one of the two subspecies of the second isoacceptor of this tRNA ($tRNA^{Asp}_{2b}$): pG-G-U-G-C-C-G-U-A-$m^2$G-C-G-ψ-A-G-D-Gm-G-C-A-R-C-G-Y-G-A-C-U-C-U-Cm-U-nQ-U-C-A-A-A-G-A-G-U-G-G-$m^7$G-A-$m^5$C-N-U-G-A-G-T-ψ-C-G-$m^1$A-U-A-C-U-C-A-A-C-G-G-C-A-C-C-G-C-C-$A_{OH}$. The structure was derived by using two separate techniques where one method provided the nucleotide sequence of the molecule from the 5′ end of the molecule and the other from the opposite (3′) end of the molecule. The results indicate that this polynucleotide of 75 residues contains eleven minor, modified nucleosides: two pseudouridine (ψ) and one each of 1-methyladenosine ($m^1$/a), 2′-O-methylcytidine (Cm), 5-methylcytidine ($m^5$C), 2′-O-methylguanosine (Gm), 2-methylguanosine ($m^2$G), 7-methylguanosine ($m^7$G), 5-methyluridine (T), 5,6-dihydrouridine (hU), and a hypermodified mannosylqueuosine (nQ). The residue N in position 49 is uncharacterized, R in position 22 is a purine residue, and Y in position 25 is a pyrimidine residue.

The tRNA contains four base pairs in the D-stem, five residues in the "small variable" loop ($D_4V_5$ type), and seven residues in the D-loop. When this structure is compared with another $D_4V_5$ type tRNA whose tertiary structure is known ($tRNA^{Phe}$ from yeast) the results indicate that this mammalian tRNA can form seven tertiary base pairs in a fashion analogous to those found in the $tRNA^{Phe}$ structure. The remaining two tertiary base pairs though can exist in this structure but in a different form (in positions 9·23·12 as A·C·G and 13·22·46 as $\psi$·R·$m^7G$).

ROLE OF A MODIFIED NUCLEOSIDE (QUEUINE) ON TRANSFER RNA FUNCTIONS. Ram P. Singhal and Randall A. Kopper, Department of Chemistry, Wichita State University, Wichita, Kansas 67208.

The role of a modified nucleoside, queuosine (Q), has been studied in order to establish a cause and effect relationship between the undermodification of liver aspartate (tRNA) and its altered properties in protein synthesis. Our earlier work has shown significant differences in G to Q modification during development and aging. Here, we have studied the aminoacylation kinetics and codon binding properties of both undermodified (G-tRNA) and normal (modified, Q-tRNA) tRNAs.

The $K_m$ value was the same for each kind of tRNA substrate (94 nM). But, the $V_{max}$ of the aminoacylation reaction using the Q-tRNA was 16-fold higher than that with the G-tRNA ($V_{max}$: 0.42 vs. 0.025 pmol per min). Thus, undermodification of the aspartate Q-tRNA results in a molecule which is a competitive inhibitor of the normal tRNA in the aminoacylation reaction.

The results of ribosome-directed codon binding studies indicate that the mammalian aspartate Q-tRNA prefers GAC over the GAU codon by a factor of two to one. On the other hand, aspartate G-tRNA prefers the GAC over the GAU codon only marginally (15% less binding with the GAU codon). Our findings of these codon preferences for the mammalian aspartate G- and Q-tRNAs are in contrast with those reported for the bacterial G- and Q-tRNAs by others.

This work indicates that in general, Q-deficient isoacceptors (G-tRNAs) in a given biological system could control effectively protein synthesis at the translation level.

STUDY OF PROTEIN AND NUCLEIC ACID INTERACTION. Vikram N. Vakharia and Ram P. Singhal, Chemistry Department, Wichita State University, Wichita, Kansas 67208.

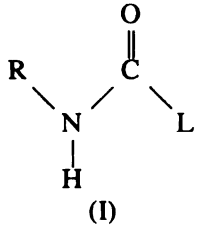
Interaction between transfer RNA (tRNA) and its cognate aminoacyl-tRNA synthetase is studied here in order to understand the nature of the protein-nucleic acid interactions. We have studied differences in the reaction kinetics of the aminoacylation reaction using two isoacceptors and two subspecies of each isoacceptor of mammalian aspartate tRNA and its cognate synthetase.

The two isoacceptors of aspartate tRNA were purified extensively and each isoacceptor produced two subspecies by gel electrophoresis. The two isoacceptors showed substantially different aminoacylation kinetics. For example, the second isoacceptor (2a + 2b) served as a better substrate (38% higher $V_{max}/K_m$) than the first (1a + 1b). Although both the isoacceptors produced two subspecies, only one of the two subspecies of the first isoacceptor (1a) was active but each subspecies of the second isoacceptor was active. For example, subspecies 2a was most reactive, having $K_m$ = 82 mM and $V_{max}$ = 1.1 pmol/min and a 63% higher $V_{max}/K_m$ value than 2b. The results indicate that the aminoacyl-tRNA synthetase interacts and catalyzes the aminoacylation reaction differently between different subspecies. Our primary results indicate that each subspecies of an isoacceptor has either an identical or very similar primary structure. The difference in the kinetic data should therefore result from the changes that exist between the tertiary structures of the subspecies. Latter changes could influence physical binding capacity between the tRNA and the synthetase or interfere with the catalysis of the aminoacylation reaction or both.

IRREVERSIBLE INHIBITORS OF ELASTASE. William C. Groutas, Department of Chemistry, Wichita State University, Wichita, Kansas 67208.

Human leukocyte elastase, a serine protease, is of great interest because of its involvement in many pathological states including pulmonary emphysema, acute arthritis, various inflammations and aging. Although a number of highly effective active-site-directed irreversible inhibitors have been developed for elastase, the presence of a highly reactive moiety in these inhibitors has enhanced their toxicity and limited their potential for therapeutic use in man.

Our efforts in this area have resulted in the development of a new class of inhibitors of elastase (I). These compounds (I) appear to function as suicide inactivators of the enzyme. The efficiency of these compounds in inactivating the enzyme is greatly diminished when the leaving group is changed from imidazole to triazole. Our results and postulated mechanisms of action for these compounds will be discussed.




(I)

L = Imidazole and 1,2,4-triazole

R = n-butyl, n-propyl, iso-propyl

A MODIFIED TECHNIQUE FOR ISOLATING RAT LIVER KUPFFER CELLS. Ellen Lewis, Marie Butler, and Larry Smith, H. L. Snyder Memorial Research Foundation, Winfield, Kansas 67156.

The method of Mills & Zucker-Franklin for isolation of kupffer cells has been modified to produce a population of cells with 90–95% purity. The method consists of sequentially treating perfused liver with collagenase followed directly by pronase for 1 hour at 37°C. After centrifugation and resuspending in a suspension buffer prepared for parenchymal cells as described by Seglen the cellular material was further incubated with a combination of pronase and DNase to destroy the parenchymal cells. The kupffer cell suspension was centrifuged and washed 2 times with a HEPES buffer solution containing $Na^+$, $K^+$, $Ca^{++}$, & $Cl^-$. The cells obtained were then filtered through a 10 $\mu$ mesh nylon filter in a small Amicon filtering apparatus with slight pressure. The cells in the filtrate were finally centrifuged again and weighed. Approximately 200–300 mg of cells were typically obtained from 7.5–8.5 gm liver with a viability of 70–95%. The activation of pyruvate kinase by fructose-1, 6-diphosphate as described by Van Berkel et al. as a criterion for purity of kupffer cells ranged from 1.3 to 3.2 fold.

These cells were studied as part of a long range project to determine if cellular selectivity could be observed during chemical hepatocarcinogenesis. Although very preliminary and too premature to make conclusions, data obtained to date may indicate the SAMP lyase is either activated or synthesized to give a 5 to 10 fold increase in activity in kupffer cells while little if any increase was seen with AMP deaminase. Both of these enzymes are components of the adenine purine nucleotide cycle and both have been shown to display an increase in whole liver during the early stages of hepatocarcinogenesis.

INCREASING CELLULOLYTIC ENZYME PRODUCTION IN SUBMERGED CULTURES OF *TRICHODERMA REESEI* AND *PLEUROTUS OSTREATUS*. William Ellerman, Debbie Miller, William Crowley, Pat Curran, Sukh Bassi and Eugene Dehner, Department of Biology, Benedictine College, Atchison, Kansas 66002, and Earlene Hegarty and Jack Freund, Midwest Solvents Co., Inc., Atchison, Kansas 66002.

Active cellulases from the mold *Trichoderma reesei* are capable of hydrolysing cellulose. The complex of cellulase enzymes hydrolyze the beta −1,4 polysaccharide linkage into individual glucose units, from which ethyl alcohol can be produced. Production of cellulases and cellobiase can be increased by culturing *T. reesei* and *Pleurotus ostreatus*, a white wood rotting fungus, in a combined culture. The organisms were grown on 8% cellulose media containing a combination of mineral salts. *P. ostreatus* produces lignase, an enzyme which breaks the lignin seal found around cellulose. Normally *T. reesei* stops producing the cellulolytic enzymes when

glucose concentration becomes too high. It appears that the combined cultures of *P. ostreatus* and *T. reesei* form a symbiotic relationship by which the glucose level is kept low enough for the cellulolytic enzymes to be more abundantly produced. The results show a slightly higher production of the cellulase enzymes and significantly higher production of cellobiase by a combined culture of the molds. It is hoped that by varying the environmental factors and the media composition it may be possible to further increase the production of these enzymes.

EXTRACTS FROM OAK TREES STIMULATE GROWTH IN VARIOUS FUNGI. Martin J. Huss, Sukh Bassi and Eugene Dehner, Department of Biology, Benedictine College, Atchison, Kansas 66002.

Earlier reports from various authorities have given credence to the idea that fungal growth can be increased by the use of wood extracts. In the light of such evidence it was determined to investigate whether or not the water extracts of the white oak tree, *Quercus alba* L. and the black oak tree, *Quercus velutina* Lam. contained substances promoting the growth of certain fungi. The fungi, *Morchella esculenta, Trichoderma reesei, Pleurotus ostreatus* and a species of *Aspergillus* were investigated to determine what effect oak extracts had on growth and sporulation. Growths of vegetative mycelia were compared on culture plates containing the appropriate agar media for the specific fungi and on complementary agar media containing diluted oak tree extracts. Oak tree extracts were prepared by boiling roots, twigs, bark and leaves in water and combining the filtered tea-like extracts. *M. esculenta, P. ostreatus* and the *Aspergillus* species were found to grow significantly better on the oak-supplemented media. The growth of *T. reesei*, with oak-supplemented media, grew only slightly better than the control groups, however sporulation seemed to be increased by the addition of the oak extracts. This increase in sporulation was also evident in *Aspergillus*. The chemicals in the oak extracts that apparently promote the growth of the fungi are currently being investigated.

INCREASED PRODUCTION OF BETA-LACTAMASE UNDER ANAEROBIC CONDITIONS IN SOME STRAINS OF *SHIGELLA*. Kris A. Canfield, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208, G. R. Miller, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208, and E. H. Gerlach, St. Francis Hospital, Wichita, Kansas 67214.

Sixteen beta-lactam antibiotic resistant clinical isolates of *Shigella sonnei* were screened for increased production of beta-lactamase under anaerobic conditions using a microbiological assay similar to that used by Thornsberry et al. (1978). Eleven of sixteen strains were found to have increased beta-lactamase activity when incubated under anaerobic conditions. These re-

sults will be confirmed quantitatively using a microiodometric assay for beta-lactamase activity in cell lysates prepared from cells grown under aerobic and anaerobic conditions.

THE EFFECT OF TEMPERATURE ON THE RNA OF *AEROMONAS* SPECIES. Bruce Ramundo and Rodney J. Sobieski, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

*Aeromonas* species previously isolated from various environmental sources were grown at two temperatures (25° and 35°C). These isolates when grown and submitted to thirty-six major biochemical tests at 25°C had reactions characteristic of an *Aeromonas* sp., but these same isolates when grown and submitted to the same tests at 35°C showed reactions characteristic of species in the family *Enterobacteriaceae*. Using RNA competition hybridization it was determined that the RNAs of isolates grown at 25° and 35°C were not homologous indicating that growth temperature perturbs RNA transcription.

GENETIC STUDIES OF FIELD REACTION TO WHEAT SOILBORNE MOSAIC VIRUS IN WINTER WHEAT. Rashied Modawi and E. G. Heyne, Agronomy Department, Kansas State University, Manhattan, Kansas 66506.

Wheat soilborne mosaic is one of the most destructive diseases of wheat, *Triticum aestivum* (L.) in Kansas. It survives in the soil and an estimated 2,000,000 acres of the Kansas wheat land is infested with this disease in the eastern one-half of the state. It is especially severe in the major wheat area in South Central Kansas. The only control is through use of resistant cultivars. We have not been able to control the expression of the disease in the greenhouse or field and are dependent on natural infection in the field for our studies. The inheritance has not been adequately described. The common expression in Kansas is a yellow foliage (chlorotic), reduced tillers, and stunting. Yields of susceptible cultivars are often reduced 50%. Our genetic studies involved seven cultivars: Gage and Eagle were susceptible with different recovery rates; Shawnee, Oasis, KS73148, and KS73256 were resistant; and Centurk gave variable responses in the field. Studies in infested fields near Manhattan, Kansas, in 1978, 1979, and 1980 indicated that one major factor was responsible for resistance. Expression of the disease in 1978 and 1979 suggested two or three factors could be involved but the symptoms were clearer in 1980 and moderately susceptible lines in 1979 were susceptible to WSBM in 1980. The variable response of Centurk was attributed to a mixture of resistant and susceptible genotypes. The four resistant cultivars, although of different origins, all had the same response for resistance.

SPIN-SPIN RELAXATION IN THE PHOSPHORESCENT TRIPLET STATE OF QUINOXALINE AT 1.4 K. Monty L. Fetterolf and A. M. Nishimura, Department of Chemistry, Wichita State University, Wichita, Kansas 67208.

Quinoxaline has been a molecule of numerous studies by triplet state spectroscopists, because of the favorable symmetry of the naphthalene-like molecule. The delocalized nature of the excited electrons in the lowest triplet n,$\pi^*$ state enable the electrons to sample perturbations affecting the entire orbital space. We have used both conventional and pulse optically detected magnetic resonance spectroscopy to observe: a). the effect of nitrogen substitution into a naphthalene molecule, and b). solvent effects in which the quinoxaline molecule was doped in a small amount into different solvent types. The spin-spin relaxation in these systems were observed and the experimentally obtained data were fit to theoretically derived equations describing the spin relaxation. The results will be discussed in terms of various line-broadening theories.

OPTICALLY DETECTED MAGNETIC RESONANCE OF BENZOYL-PYRIDINES AND PYRIDYL KETONES. Steven G. Hilburn and A. M. Nishimura, Department of Chemistry, Wichita State University, Wichita, Kansas 67208.

Past studies of the lowest phosphorescent excited electronic state of benzophenone showed the excitation to be localized on the carbonyl portion of the molecule. Of interest are the effects of intramolecular interactions on localized n,$\pi^*$ states, because of the sensitivity of the excited triplet state to perturbations. A simple interaction is that of lone-pair electrons of nitrogens of heterocyclic rings with the localized triplet electrons of excited benzophenone-like molecules. Conventional and pulse optically detected magnetic resonance were observed in several nitrogen heterocyclic benzophenone molecules. Results indicate that the interaction leading to a decrease in spin-spin relaxation time is distance dependent. The mechanism of the interaction is system dependent.

A LAMB-SHIFT MEASUREMENT IN OXYGEN. Basil Curnutte and C. Lewis Cocke, Department of Physics, Kansas State University, Manhattan, Kansas 66506.

The quantum electrodynamic corrections to the binding energy of a charged particle in an electric field can be tested by comparison of the theory and measurements of the Lamb-shift. There are currently two techniques of carrying out the quantum electrodynamical calculation of the Lamb-shift: one by Erickson is an analytic approximation of the terms above $Z^6$ in a series expansion in atomic number, the other by Mohr is a direct numerical

evaluation to all orders in Z. We are currently undertaking the measurement of the Lamb-shift by measuring the anisotropy of the Stark quench radiation from hydrogen-like oxygen. This technique will be compared to others and preliminary results discussed.

DISSIPATIVE FORCES AND QUANTUM MECHANICS. John S. Eck, Department of Physics, Kansas State University, Manhattan, Kansas 66506.

The dissipative forces of classical mechanics can be included in quantum mechanics by the use of non-Hermitian Hamiltonians. The Ehrenfest theorem for such Hamiltonians is derived, and simple examples which show the classical correspondences are given. The viscosity coefficient for a nuclear collision is estimated.

A NUMERICAL SOLUTION TO THE PROBLEM OF THE QUANTUM BOUNCING BALL. Richard D. Desko and Donald J. Bord, Department of Physics, Benedictine College, Atchison, Kansas 66002.

The one-dimensional Schrodinger equation for a "ball" bouncing in a uniform gravitational field is solved numerically as an example of how, through the use of the computer, more advanced problems can be successfully solved by undergraduates in beginning quantum mechanics courses. In particular, methods for determining the allowed energy levels for large values of particle position using Chebyshev expansions are discussed. This solution is then examined in light of the correspondence principle and compared to the predictions of the Bohr-Sommerfeld quantization rule.

THE SEARCH FOR HEAVY METALS IN CP STARS—IOTA CORONA BOREALIS. J. P. Davidson, Department of Physics and Astronomy, University of Kansas, Lawrence, Kansas 66045, and Donald J. Bord, Benedictine College, Atchison, Kansas 66002.

Our investigation of the ultraviolet spectra of chemically peculiar (CP) stars obtained from the high dispersion data from the International Ultraviolet Explorer (IUE) has been extended to the Hg-Mn star Iota Corona Borealis in the wave length range 1230–2121 Å. We have searched for heavy elements in the range $74 \leq Z \leq 81$ as well as the odd elements P, Mn, Ga and Y using the statistical line identification methods of Hartoog et al. (Ap. J. *182*, 847 (1973)). There is evidence indicating the presence of MnII and possible Au although the latter is still uncertain. Searches for other of the heavy metals is hampered by the lack of laboratory measurements of the line spectra in the vacuum ultraviolet shorter than about 2000 Å. Our analysis of the presence of the other elements searched for will be discussed.

REMOVAL OF THE RESTRICTION LIMITING APPLICATION TO ONLY INTEGER QUANTITIES IN THE DESIGN OF SYMBOLS REPRESENTING NUMERICAL VALUES WHEREIN THE VISUAL APPEARANCE OF EACH SYMBOL IS UNIQUELY ESTABLISHED BY THE QUANTITY IT REPRESENTS AND, AT THE SAME TIME, EACH CHANGE IN VALUE PRESCRIBES A PREDICTABLE CHANGE IN SHAPE. Raymond C. Hall, Chemical Engineering Department, Kansas State University, Manhattan, Kansas 66502.

The mechanics of generating particle distributions (upon which distributions the shaping of symbols is based; with shapes embodying visual properties which 1) uniquely represent specific integer quantities and 2) visually show changes in form of symbol in accord with changes in values) introduce or feed discrete particles into a conceptual machine. Within this machine the discrete particles are processed to generate a specific distribution of particles through a series of "multiple-doubling" chambers. The distribution of particles contained within the array of chambers is an exact and specific function of the total number of particles held within the machine and this distribution is the basis upon which symbols are shaped.

Examples are given in this paper to illustrate how changes in numerical values prescribe changes in shapes of symbols. Such applications to changes generated through addition, multiplication and subtraction are straightforward. In division, however, quantities having values less than unity and greater than zero are generated and the question is introduced of how the concept of multi-doubling chambers can be utilized to establish distributions which dictate shapes of symbols within this range of values.

This paper handles this question by employing the concept of "multi-halving," basically the reverse of multi-doubling, to generate "parts-of-particles" which can be used to develop distributions through the same chambers as were used for integer quantities and, consistent with practices established for integer values, uses these distributions as a basis for shaping symbols to represent quantities having values between one and zero. This removes the restriction of application to only integer quantities.

This paper notes that the rules for and nomenclature of punctuation, as devised for base ten, are inappropriate for the new system.

COPPER, A UNIFYING ELEMENT FOR DEPARTMENTAL RESEARCH. Alfred T. Ericson, Department of Chemistry, Emporia State University, Emporia, Kansas 66801.

The faculty members of academic departments traditionally pursue research based on their area of specialization, with little attempt to coordinate efforts within the department. Each individual is truly working alone and in a small department often must teach each student the basic techniques required for research. Five members of the chemistry department at Emporia

State University have chosen copper as the unifying element for a long term investigation. A variety of techniques for copper analysis (titrations, electrodeposition, colorimetry, atomic absorption) are included in the analytical chemistry course and the chemistry of copper is emphasized in the departmental seminar program. The proposed research projects included: "The effects of structure on complexes of copper" with Dr. Gimple; "The role of copper in mechanisms of organic reactions" with Dr. Johnson; "The effects of copper ions on growth of alfalfa" with Dr. Smalley; "The heats of solution of copper salts in aqueous and non-aqueous solvent systems" with Dr. Greenlief; and "Form and amount of copper in soil and water" with Dr. Ericson. The major reason for choosing copper was that it was interesting to all of our staff and we felt a unifying element of this type could stimulate our students' interest in research. The project is expanding and we believe it could provide a useful model for many programs.

READABILITY MEASURES OF SOME SCIENCE TEXTBOOKS. Richard C. Sapp, Department of Physics and Astronomy, University of Kansas, Lawrence, Kansas 66045.

One characteristic of science textbooks which might be considered in making text selections for courses is an estimate of its readability for the students. A large number of measures of readability have been proposed. I have applied two commonly used ones, by E. Fry and by F. R. Flesch, to choosing a text for an inquiry-based physical science course for elementary education majors where both PSNS (brief edition) and Arons' "The Various Language" have been used. The two different measures were compared for consistency. Differences in reading levels, if significant, should be related to the expected reading levels of the student population involved. This should be weighed against other considerations such as organizational format, content presentation, topic selection, problem lists, and stylistic felicity as judged by the instructor.

INFUSION OF ENVIRONMENTAL CONSERVATION CONCEPTS AND UNDERSTANDINGS INTO THE SCHOOL CURRICULUM. Thomas A. Eddy, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

A great number of elementary and secondary school educators are concerned with environmental problems, but many either do not see a viable connection between these problems and their instructional programs, or they do, but are uncertain as to what is the most practical method for incorporating such concerns into daily instruction. This study examined the use of infusion units as an acceptable method of integrating environmental conservation concepts and understandings into the educational process. Programs of environmentally oriented instruction were developed in the

subject matter areas of language arts, fine arts, health, mathematics, science, and social science. These infusion units were used to supplement or supplant some of the units of instruction used normally in the course of study. When properly planned this approach was found to satisfy both the regular subject matter objectives and the environmental objectives.

SIZE AND SHAPE CHARACTERISTICS OF VOLCANIC ASH AS AN INDICATOR OF DISTANCE FROM THE SOURCE. Douglas J. Schultz and Charles E. Pumroy, Department of Geology and Geography, Wichita State University, Wichita, Kansas 67208.

Analysis of the particle size and shape of ash erupted on 18 May 1980, from Mt. St. Helens shows that these parameters are useful in determining the distance of ash transport. Because the interaction of size and shape of minerals may influence the settling velocity, each variable was analysed. Quantitative measurement of grain shape was performed using closed form Fourier series analysis. Shape measurements of the total ash demonstrated that the amplitude variation of the second, ninth, seventeenth, and nineteenth harmonics are sensitive to distance from the source. The bulk of the total ash is glassy material and these grains would not be expected to retain their original shapes after burial and diagenesis. Magnetite grains were selected for further study, and no variation of shape with distance was found. However, the mean and median grain size, sorting, and skewness of magnetite size distributions correspond to distance of transport. Therefore, 1) in unaltered ash deposits, the shape of total ash may be used to supplement or complement traditional grain size measurements; and 2) magnetite grain size should prove to be a useful indicator of source proximity where original glassy material has been altered.

SENSITIVITY OF KANSAS MICROEARTHQUAKE NETWORK. Anne F. Sheehan and Don W. Steeples, Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66044.

In 1977 and 1978, a total of nine seismograph stations throughout eastern Kansas were established by the Kansas Geological Survey (KGS) as a means to explore microearthquake activity within the state. The stations continuously telemeter seismic signals to the KGS building in Lawrence where records are changed and monitored daily. In its first three years of operation, the KGS seismic network has detected 68 earthquakes in Kansas ranging in Richter magnitude from 1.1 to 3.1. A recent study of the KGS seismic network explored the sensitivity of this system. The ability of each seismograph station to record earthquakes of various magnitudes as a function of epicentral distance was investigated and a series of magnitude *vs* distance graphs resulted. These graphs and the interpretations of them revealed several facts about the KGS seismic network: 1) although scattered

throughout all of eastern Kansas, the sensitivities of the nine seismographs are nearly identical; 2) the capacity of the network to monitor seismic activity in eastern Kansas is excellent down to magnitude 1.5 and is sufficient to detect events to magnitude 2.3 in western Kansas. Detection radii for 1.5 events range from 145 km for the Emporia seismograph station (EMK) to 225 km at Tuttle Creek (TCK); and for a magnitude 2 event, from 245 km at EMK to 385 km at TCK.

IMPORTANCE OF RED BED SEDIMENTS RELATIVE TO THE FORMATION OF PERMIAN STRATIFORM COPPER DEPOSITS. I. GENESIS OF STRATIFORM COPPER DEPOSITS: DISCUSSION OF POLISH OCCURRENCES. Stanislaw Speczik, Department of Geology, University of Warsaw, Warsaw, Poland, and Pieter Berendsen, Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66044.

Although a variety of opinions are held regarding the origin of stratiform copper deposits, a syngenetic process is favored by most workers. Major differences evolve around the supposed source of the metals and the manner in which they are ultimately concentrated in their final configuration. The intimate association with oxidized "red bed" sediments is widely acknowledged. In our study, we like to compare the Polish and U.S. Midcontinent deposits because they show many similarities.

The basal Upper Permian stratiform copper deposits in Poland are believed to be of similar origin as those known to occur elsewhere in the sedimentary basin which stretches from southeastern England through Germany to Poland. The copper deposits in Poland are the largest in Europe and occur in sediments deposited in a shallow, marine, euxinic environment. Presently, they are located adjacent to the Sudetian Mountains, and separated from them by a set of basin and range type faults. Copper is the main ore metal, but considerable quantities of lead, zinc, silver, and other metals are also present. A complex basinward zonation is apparent. All sulfide is considered to be of biogenic origin and a direct relationship between organic carbon and heavy metal concentration exists.

It is generally accepted that the metals were supplied to the basin by both leaching and reworking of the uppermost Lower Permian red sandstones, and by erosion of rocks from the adjacent highlands.

IMPORTANCE OF RED BED SEDIMENTS RELATIVE TO THE FORMATION OF PERMIAN STRATIFORM COPPER DEPOSITS. II. COMPARISON OF POLISH AND U.S. MIDCONTINENT OCCURRENCES. Pieter Berendsen, Kansas Geological Survey, University of Kansas, Lawrence, Kansas 66044, and Stanislaw Speczik, Department of Geology, University of Warsaw, Warsaw, Poland.

Permian stratiform copper deposits occur widespread throughout the

world. The deposits show gross similarities; however, each deposit has its own characteristics which seem to set it apart from the others. The question which naturally arises is whether the formation and emplacement of the deposits is governed by one major process with minor variations in detail depending upon the geologic and geochemical environment, or whether the master processes are basically different. The geological and mineralogical characteristics of the U.S. Midcontinent and the Polish deposits are reviewed. The main similarities are: (1) Deposits occur in Permian rocks which were laid down in shallow marine basins and mineralization is uniform over large areas; (2) Mineralization is confined to definite reduced units within the generally oxidized Permian complex; (3) The Permian basins were developed on the stable Precambrian platform; (4) Lack of evidence between tectonism and mineralization; (5) Nature of the ore minerals within the deposits is similar; (6) Positive correlation between organic carbon and heavy metal sulfides. Important differences are: (1) The structural development of the basin and the history of igneous intrusives activity; (2) The mineralogical compositions of the deposits, probably due to differences in primary source; (3) The type of mineral and element zonation; (4) The U.S. Midcontinent deposits contain several mineralized units; the Polish deposits are confined to a particular interval. We suggest that the heavy metals are mobilized by leaching from the oxidized Permian sediments closely associated with the deposits. The specific processes responsible for the concentration of the heavy metals in their final configuration differs between the deposits.

GEOLOGY OF THE BAYHORSE MINING DISTRICT, CUSTER COUNTY, IDAHO. Michael E. Nelson and Lynn D. Vogler, Department of Earth Sciences, Fort Hays State University, Hays, Kansas 67601.

Production of lead, silver and other base metals in the Bayhorse Mining District of central Idaho has been sporadic over the last century. Major production occurred from 1877–1900 and most large mining operations were suspended over 50 years ago. However, recent geological exploration has shown that fluorspar is present in large quantities; thus, mining and production of fluorite may begin in the near future.

The Bayhorse Region is underlain by a thick sequence (≈3000 m) of early Paleozoic sedimentary rocks that are intruded on the west by the Cretaceous "Idaho Batholith" and largely covered on the east by the early Cenozoic Challis Volcanics. Although fluorite mineralization can be found in fracture filling and in fault and breccia zones in the Garden Creek Phyllite, Ramshorn Slate and Challis Volcanics, most stratabound fluorite occurs in the upper part of the Bayhorse Dolomite.

ORIGINS OF MOTTLING IN THE MIDDLE CAMBRIAN DEATH CANYON LIMESTONE MEMBER (GROS VENTRE FORMATION) BASED ON PETROGRAPHIC OBSERVATIONS. Daniel A. DeBoer, Department of Earth Science, Fort Hays State University, Hays, Kansas 67601.

The Death Canyon Limestone Member contains locally extensive, iron-stained, dolomitic mottling. The origins of most of this mottling may be related to the following processes: 1) burrowing, 2) neomorphism, and 3) stylolitization.

Mottling associated with burrowing activity results when the original homogeneous micritic texture was interrupted by the creation of a network of permeable avenues (burrows) through which magnesium-rich brines migrate. The result is selective dolomitization of the more permeable avenues leaving the surrounding micrite relatively unaltered.

Mottling related to neomorphism often consists of irregular patches of dolomite floating in neomorphic spar and surrounded by unaltered micrite. This fabric selectiveness indicates a close permeability control over the dolomite distribution which would occur only if intercrystalline porosity and permeability in the neomorphic spar is relatively greater than in the micritic matrix. The migration of magnesium-rich brines follows the more permeable avenue in the neomorphic spar and results in selective dolomitization of the spar.

Mottling related to stylolitization often occurs as irregular patches of dolomite that roughly mimics stylolite topography. These dolomite patches gradually decrease in density away from the stylolite. The dolomite is formed as a result of pressure-solution when magnesium-rich fluids react with the micrite. The calcite lattice yields calcium ions and dolomite is precipitated.

THE PETROLOGY OF THE REAGAN SANDSTONE (LATE CAMBRIAN), WICHITA MOUNTAINS, OKLAHOMA. Terry R. Cullen, Department of Geology and Geography, Wichita State University, Wichita, Kansas 67208.

The Reagan Sandstone is the basal Paleozoic sedimentary formation of Oklahoma, and outcrops along the north flank and southern margin of the Wichita Mountains of Oklahoma. It lies unconformably on the erosional surface of the Carlton Rhyolite (Middle Cambrian) in the Wichita Mountain Province. Petrographic examination of the Reagan Sandstone reveals several distinct lithologies: 1) a medium-grained, iron-stained, quartzose sandstone, containing rhyolite rock fragments; 2) a laterally discontinuous iron-

stone, containing chamosite and hematite oolites; 3) an argillaceous, highly glauconitic sandstone, containing limestone and dolostone lenses; 4) a very fine-grained, calcareous, feldspathic sandstone.

Composition and texture of plagioclase feldspar suggests local, dual sources for the feldspar of the Raggedy Mountain Gabbro Group and the Wichita Granite Group, both of which outcrop in the igneous core of the Wichita Mountains. The source of the carbonate cement and lenses in the Reagan is probably the overlying Honey Creek Formation and Lower Arbuckle Group. The carbonate cement formed as a result of dissolution of carbonate in the overlying limestones and dolostones, and was transported downward into the Reagan Sandstone by groundwater movement. X-ray diffraction analysis indicates the presence of well-ordered glauconite. Some of the glauconite formed as the result of alteration of rock fragments and feldspar, as evidenced by the presence of partially altered rhyolite and granite rock fragments. Much of the glauconite is not associated with the alteration of parent material, and may have formed as the result of organic activity contemporaneous with the deposition of the Reagan Sandstone.

TWO-ICE-LOBE MODEL FOR GLACIATION OF KANSAS. James S. Aber, Geoscience Department, Emporia State University, Emporia, Kansas 66801.

It is now known that continental ice advanced into Kansas and adjacent Missouri several times during the early Pleistocene. It has been generally concluded that ice advanced each time as a single broad lobe coming from the north or northeast. This simple view contrasts with the known complexities of the younger Wisconsin glaciation, and indeed there is much evidence that the glaciation of Kansas was also more complex. Wisconsin glaciation of the northern Plains region serves as a model for earlier, more widespread, glaciations of the same region. Prominent features of the Wisconsin glaciation were two major ice lobes—the Des Moines lobe in Minnesota and Iowa and the James River lobe in the Dakotas, which advanced southward along lowlands either side of the Coteau des Praires—an upland underlain by a core of Cretaceous sedimentary rocks and Precambrian Sioux Quartzite. The Missouri River above Sioux City and the upper Des Moines River developed as Wisconsin ice-marginal drainages, while the Big Sioux River represents an interlobate drainage. A similar set-up probably developed during the Kansan glaciation. "Dakota Ice" advanced southward through the Dakotas, across Nebraska, and into Kansas, while "Minnesota Ice" advanced from Minnesota, through Iowa, and into Missouri. These two ice flows were separated by the Coteau des Praires, which though covered at glacial maximum still obstructed ice movement. The Big Blue/Kansas/lower Missouri Rivers system developed for ice-marginal drainage near

the Kansan maximum, whereas the Missouri River above Kansas City came into being as an interlobate drainage during deglaciation. The Kansas City reentrant and the Missouri River north of Kansas City mark the approximate boundary between the two ice flows. Interplay between Dakota and Minnesota advances would nicely explain both structural (Dellwig & Baldwin, 1965) and striation (Schoewe, 1941) data for two (or more) directions of glaciation in northeastern Kansas. Additional field studies are clearly needed to test this two-lobe glaciation model for Kansas. Afton, Iowa—the original type locality for Kansan and Nebraskan tills—lies in the region influenced by the Minnesota ice. Attempts to carry stratigraphy at this site westward into the region dominated by Dakota ice have led to much confusion (Hallberg & Boellstorff, 1978). Glacial stratigraphy west of the Missouri River should be reinterpreted in light of this new model.

HYDROGEOLOGY OF PREGLACIAL CHANNELS, NORTHEAST KANSAS. Henry V. Beck, Department of Geology, Kansas State University, Manhattan, Kansas 66506.

A dendritic drainage pattern had developed in bedrock of northeast Kansas before the advance of the Kansas glacier into the area. Much of this pattern had perhaps developed before the advance of the Nebraskan glacier. Some of this drainage was tributary to the ancient Missouri River System, which some might refer to as the Grand River.

No correlation between the buried drainage and present drainage exists on a regional scale. Some geomorphic studies indicate the present Little Blue and Vermillion rivers of southern Marshall County follow the ancient system. Glacial and glaciofluvial deposits in that part of Kansas have buried valleys cut by streams in Late Tertiary-Early Pleistocene time. Subsequent erosion has destroyed the geomorphic features of Kansan deposition. Existence of the features is recognized by the nature of the deposits. The earliest deposits are composed of fragments of chert and some limestone from formations belonging to the Gearyan Series. Later deposits do contain significant quantities of feldspar, quartz, quartzite and other foreign rock (erratics) in the gravel-sized sediments.

Several rural water districts and small municipalities produce water from wells constructed in these valleys. Well yields range up to 250 gallons per minute (gpm) and the water is of excellent quality. The water of good to excellent quality indicates a short residence time in the aquifer. In some deeper zones, iron and manganese are present in amounts above limits. Recharge to the aquifer must be by infiltration through sandy till zones principally in the ephemeral channels of the present drainage. Aquifer tests to date indicate high transmissivities and storativities characteristic of confined aquifers.

THE KANSAS AGRICULTURAL LANDSCAPE: REGIONS AND REGIONAL PROFILES. Huber Self and H. L. Seyler, Department of Geography, Kansas State University, Manhattan, Kansas 66506.

The paper reports on a project with two objectives. First the study developed an information base and derived an areal taxonomy with numerical and narrative profiles of agricultural regions in Kansas. This element provides an accurate, synoptic view of agricultural development as well as a context for subsequent research into selected facets of agricultural activity. Second, an objective system was specified permitting (1) replication for later updating of regions; (2) replication for several temporal cross-sections to facilitate analyses of compositional change in agricultural landscapes; and (3) a focus on one or more segments in the larger complex of agricultural activity, such as crops, animals, or farming operations, in one or more periods.

One-hundred twenty indices for commodity production levels, commodity shares of farmed land, land characteristics, and farming operation were refined to seventy-two variables. These were reduced by factor analysis to yield seventeen principal dimensions of variability in agricultural attributes for county units. Counties were then rated on each principal dimension to obtain comparable profiles. A clustering procedure produced groupings of counties (regions) with similar profiles. Narrative descriptions were then prepared for forty-five regions.

PERCEPTIONS OF KANSAS LANDSCAPES: THREE VIEWS. Roxane M. Fridirici, Department of Geography, Kansas State University, Manhattan, Kansas 66506.

Kansas has suffered from the widely-held perception that it is a flat, drab, windy state. This paper reflects a research project which compared the perceptions of Kansas landscape with other landscapes from around the country by three groups of students: Kansans, out-of-state, and international students. A projective technique was used in which they rated 31 slides numerically on the basis of appeal or desirability, and then rated the same slides subjectively, by writing a brief description of what factors in the landscape led them to score the slide as they did. A preference score for each slide was figured, and a simple correlation of landscape preference scores between paired combinations of the respondent groups were computed for both Kansas and non-Kansas landscapes. These preferences were compared with the written responses. The most striking aspect of these results was the usually small differences in preference between the Kansas and the out-of-state groups, and the frequent discrepancy between the preference scores and the subjective responses. Kansans generally perceived their landscapes in a more favorable light than the other groups, though the subjective responses were not uniform within the group. The idiosyncratic nature of the subjective responses provided insight into the individual im-

ages of the landscape, and also underlined the analytical pitfalls for the unwary investigator.

KANSAS AND THE WESTERN IMAGE: THE SPATIAL DISTRIBUTION OF WESTERN ATTITUDES IN KANSAS. Paul E. Phillips, Department of Earth Sciences, Fort Hays State University, Hays, Kansas 67601.

Western attitudes served as a data source for an investigation within Kansas of a suggested contact between two culture regions of the United States: the West and Midwest. Western attitudes were obtained from a review of nearly a century of popular and scholarly articles and books. Measurement of the western attitudes within the Kansas population was performed via a questionnaire administered to 520 respondents at the state universities of Kansas: Emporia, Hays and Pittsburg. The results were scaled by the Guttman Method and analyzed by Factor Analysis. Factor scores were classed and plotted by respondent's home town. The results showed the presence of an East-West dichotomy in Kansas' population for only a single measured trait, willingness to travel. Western Kansans were more willing to travel many miles for such everyday needs as food and entertainment, but avoided non-essential driving such as vacations or weekend trips.

ECOLOGICAL VEGETATION MAPS. A. W. Küchler, Department of Geography, University of Kansas, Lawrence, Kansas 66045.

Ecological vegetation maps are vegetation maps on which some features of the environment are incorporated into the legend. One can distinguish vegetation maps without environmental information, those on which the distribution of phytocenoses is related to one environmental feature, and those on which vegetation and several aspects of the environment are shown.

On large scale maps, gradients in one environmental feature can be revealed by the vegetation with astonishing precision. Only few environmental features can be shown on one map, and all the others are ignored. To what extent this affects the correct interpretation of an ecological vegetation map is a problem.

Smaller scales mean the vegetation is more generalized, but the environment is generalized, too. This creates further problems in interpretation. Careful observations in the field, and experimentation can solve such problems only partially.

DREDGING AND BIOTA OF THE LOWER KANSAS RIVER. Stuart C. Leon, Division of Fishes, Museum of Natural History, University of Kansas, Lawrence, Kansas 66045.

In May 1979 a three-year study was initiated to determine the effects of the commercial sand and gravel dredging industry on fish populations in the

lower Kansas River. The study area extends from Bonner Springs to Turner Bridge at Kansas City (river miles 11.0 to 26.0). Fish and water quality sampling are conducted at three dredge sites and two control sites in nine months each year. Data from fish samples include species composition, relative biomass estimates, condition, growth, and stomach analysis. Relative species abundance for phytoplankton, zooplankton, and benthos is also determined. Dredge study sites are located progressively farther downstream to determine cumulative effects of dredging. Control study sites are upstream from all dredge sites to prevent them from being impacted by dredging activities. Preliminary data indicate that alteration of habitat is the most significant effect of dredging, with consequent effect on the biota.

*LEPTODORA KINDTI* POPULATION STRUCTURE IN LAKE READING, KANSAS. Marc J. Bowen, Division of Biological Sciences, Emporia State University, Emporia, Kansas 66801.

*Leptodora kindti* was first reported in Lake Reading in 1975. Due to its predaceous nature, *Leptodora* may influence the future species composition and standing crop of the zooplankton fauna in this lake. Population structure and seasonal occurrence of *L. kindti* in Lake Reading during 1979 and 1980 are summarized and probable prey species are identified.

RAPID LANDSAT DATE SELECTION FOR CROP IDENTIFICATION IN THE HIGH PLAINS. Elizabeth R. Kipp, Kansas Applied Remote Sensing Program, University of Kansas, Lawrence, Kansas 66045.

A method for the rapid selection of Landsat dates for crop identification in the High Plains is discussed and evaluated. Since the crop calendar is a key parameter for maximum accuracy in crop classification from Landsat imagery, Landsat dates were chosen on the basis of crop phenology and inferred spectral reflectance characteristics. The USDA's Crop and Livestock Reporting Service reports crop phenological phenomenon on a weekly basis during the growing season and because these reports are readily accessible, they were used to gather the necessary crop calendar information.

*GENETIC VARIATION WITHIN AND BETWEEN POPULATIONS OF AN ALPINE GRASSHOPPER. K. J. Hamrick, Department of Systematics and Ecology, University of Kansas, Lawrence, Kansas 66045.

*Aeropedellus clavatus* is a small, predominantly flightless grasshopper found primarily on the alpine tundra of Colorado, though populations have also been found at lower elevations. Sixteen populations were analyzed for

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* Recipient of the 1981 Tomanek Award for the best student paper presented at the annual meeting of the Kansas Academy of Science.

gene frequency variation in a nested design of two populations per mountain, two mountains per region, and five regions. All populations in regions 1–4 were located above 11,500 ft., and the two populations in region 5 were found approximately 7000 ft. An average of 42 individuals were collected from each population, brought back to the lab in cages, frozen at −80° F and subsequently analyzed by electrophoresis for 25 allozyme loci. Nei's analysis of gene diversity was used to partition the genetic variability into within-population ($G_{ST}$ = .918), between populations within mountains ($G_{ST}$ = .034), between mountains within regions ($G_{ST}$ = .019) and between regions ($G_{ST}$ = .029). Individuals from different regions were less similar genetically than individuals from within a region, with a significant positive linear correlation being found between genetic distance and geographic distance ($r$ = .345, $n$ = 120, $P < .01$). However, 91% of the total variation was found within populations. Thus, populations which currently appear to be isolated from one another are, in fact, genetically similar. Individual loci were examined for regular patterns of variation among the regions.

THE MICROANATOMY OF THE GAS EXCHANGE REGION OF THE AVIAN LUNG. William L. Sexton, Department of Anatomy and Physiology, Kansas State University, Manhattan, Kansas 66506.

The microanatomy of the lung of the chicken, *Gallus gallus domesticus*, was examined using light and transmission electron microscopic techniques. Special attention has been given to the gas exchange region in an effort to better understand avian respiratory function.

The bird lung is composed of a relatively rigid flow-through parenchyma and an air sac system which functions as a bellows to move gases thru the lung. Within the lung parenchyma there are three hierarchies of airway branching. Gas exchange occurs in the mantle of a matrix of air and blood capillaries and interstitium.

The air capillaries are formed by simple squamous epithelium analogous to mammalian type 1 cells. The airway epithelium together with paired basal laminae and the capillary endothelial cells form the gas-blood exchange barrier (>0.5 $\mu$m thick). Cuboidal surfactant-producing cells found in the atrial epithelium of the parabronchus are analogous to mammalian type 2 cells. Many fibroblasts are found within the mantle interstitium. These cells often possess a dense microtubular network and may also have a contractile function. Free nerve endings are found sparingly within the interstitium; some are possibly afferent. In addition, macrophages and migrating white blood cells are occasionally found within the interstitium.

Despite the great differences in the gross anatomical features and method of ventilation between the avian and mammalian lung the cell types in the gas exchange region are quite similar. (Supported by a grant from the College of Veterinary Medicine, Kansas State University.)

SUPPRESSION OF OVULATION WITH INTACT LORDOTIC RESPONSE IN THE FEMALE RAT VIA CYCLOHEXIMIDE INJECTION INTO THE MEDIAL NUCLEUS OF THE AMYGDALA. Edwin S. Purcell, Kenneth A. Renner and David Quadagno, Department of Physiology and Cell Biology, University of Kansas, Lawrence, Kansas 66045.

Numerous studies have employed cychoheximide (CHX) and other inhibitors of protein synthesis to investigate the presumed genomic effects of estrogen on target areas within the central nervous system. In this experiment, a .5 $\mu$l injection containing an India ink marker and either 10 $\mu$g CHX in normal saline or normal saline alone was administered bilaterally into the medial nucleus of the amygdala between 16:00 and 18:00 h on diestrous. Behavioral response was evaluated via the Lordosis Quotient (LQ) at 23:00 h on proestrus. Those animals with LQ > 40 and maintaining normal vaginal cyclicity were sacrificed at 16:00 h on the day of estrus. Oviducts were removed and flushed to determine if ova were present. Brains were later examined for accuracy of implantation. Thirty-eight percent of the CHX treated animals (N = 13) had ova present while 100% of the saline group (N = 13) ovulated. These results suggest that estrogen effects lordotic behavior and ovulation via separate mechanisms, as both CHX and saline treated rats showed high levels of sexual behavior.

FORAGING PREFERENCE AND EFFICIENCY IN THREE HETEROMYID RODENTS IN KANSAS. Gary H. Blevins, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208, and William M. Langley, Department of Biological Sciences, Wichita State University, Wichita, Kansas 67208.

Theoretically rodents avoid direct competition for seed resources by developing different foraging strategies. A current hypothesis of foraging strategies suggests that rodents differentially use naturally occurring patchy seed resources, with quadrapedal pocket mice specializing on abundant low density seed clumps and the bipedal kangaroo rats utilizing widely scattered high density seed clumps. To test this hypothesis the foraging strategies of three naturally co-existing heteromyid rodent species were investigated: a kangaroo rat (*Dipodomys ordii*) and two pocket mice (*Perognathus hispidus*) a large pocket mouse similar in size to *D. ordii* and (*Perognathus flavus*) a small pocket mouse. First, to test if each species has a foraging preference for a particular size clump of seeds, animals were provided with millet seeds in large or small clumps and these were put on the surface or buried in a systematic pattern. Removal of seeds from the foraging arena and amounts of seeds in caches were determined. To test for species differences in foraging efficiency animals were provided with millet seeds distributed in clumped or scattered patterns on the surface for one hour. Trials

were timed and number of seeds harvested were counted. Efficiencies were calculated from these measurements. The data indicate basic differences in foraging efficiency between species, particularly with time spent at piles collecting seeds. These differences suggest that predator avoidance may be an important factor affecting foraging behavior.

HERPETOFAUNA OF THE SANDSAGE PRAIRIE IN SOUTHWESTERN FINNEY COUNTY, KANSAS. Michael S. Rush, Department of Biological Sciences, Fort Hays State University, Hays, Kansas 67601.

During the summer of 1980, a baseline study was conducted on the flora and vertebrate fauna of the sandsage prairie south of Holcomb, Finney County, Kansas. The main study site was 2 miles wide (east to west) and 4 miles long, with subsequent, less intensive study of surrounding areas. The plant communities on the site were divided into four major ecosystems. From the Arkansas River moving south were the floodplain habitat, dune sands habitat, choppy sands habitat, and level sands habitat. The herpetofauna was studied using seven methods of collection: road cruising, walking transects, drift fence-pit traps, pitfall traps, funnel traps, seining, and artificial cover. Twenty species of amphibians and reptiles were recorded, seven of which were new county records. The habitat preference of each species was estimated from the trapping data.

NIDICOLOUS BIRD PARENTS INFLUENCE NEST PREDATION. Glenda A. Stark, David Coleman and Daniel E. Bowen, Department of Biology, Benedictine College, Atchison, Kansas 66002.

In order to test the hypothesis that parent birds attract predators to their nests we conducted experiments from June 1–July 4, 1981 in agricultural land along the Missouri River in Atchison County, Kansas and Buchanan County, Missouri. Nests of nidicolous species were observed during egg-laying and incubation, periods when parents attend the nest but the young have not hatched. Abandoned nests were located and stocked with either House Sparrow (*Passer domesticus*), Starling (*Sturnus vulgaris*), or Rock Dove (*Columba livia*) eggs and monitored in the same fashion as the active nests. Red-Winged Blackbird (*Agelaius phoeniceus*) egg losses per exposure day were essentially the same for active nests (0.111) and control nests (0.120) in colonies. Active nests that were isolated from colonies (>600 M) had losses (0.068) twice as great as isolated control nests (0.034). These data suggest that Red-Winged Blackbird parents attract predators but in colonies group defense reduces the predation rate. In contrast, egg losses per exposure day were lower for active Mourning Dove (*Zenaida macroura*) nests (0.027) than control nests (0.196). Apparently the presence of Mourning Dove parents reduces the chance of predation.

EAR/HORN RELATIONSHIPS OF THE AMERICAN PRONGHORN ANTELOPE, *ANTILOCAPRA AMERICANA* ORD. Paul L. Milks, Department of Biology, Emporia State University, Emporia, Kansas 66801.

One method of determining the trophy qualities of big game animals is through the use of a size relationship between two anatomical structures. For the pronghorn, the most common size relationship is that of the ears and horns.

Two ear and four horn measurements of 60 pronghorns, harvested during the 1979 and 1980 Kansas firearm hunting seasons, were statistically analyzed with appropriate statistical tests to determine if horn length could be estimated by using the ear length as a known measurement to which the unknown length of the horn was compared.

The two ear measurements were the standard ear measurement used by mammalogists and the distance from the junction of the ear and skull to the tip of the ear. The four horn measurements were total horn length, the distance from the ear tip to the top of the horn curve, prong length, and horn base circumference.

Statistical results indicated that total horn length could be estimated by comparing the unknown horn length to a known ear length, and that prong lengths and horn base circumferences could be determined from the estimated horn lengths.

GAMETOPHYTE BIOLOGY OF *GLEICHENIA BIFIDA*: A NEW DEVELOPMENTAL PATTERN. William W. Adams, III and Christopher H. Haufler, Department of Botany, University of Kansas, Lawrence, Kansas 66045.

Ferns are unique among vascular land plants in that during their life history they exist as two entirely separate and independent life forms. While it is the conspicuous sporophyte generation that is most commonly associated with ferns, it is the tiny gametophyte generation that is largely responsible for initial population establishment. When studying the adaptations of ferns to their habitats, it is important, therefore, to consider the contribution that both generations make to the success of the species. The course of development of the gametophyte from spore to sexual maturity may relate directly to the ability of the fern to exist in a particular habitat. Most fern gametophytes develop as follows: spore germination gives rise to a filament of from four to eight cells; 2-dimensional growth is initiated when the terminal cell of the filament divides parallel to the long axis of the filament; and the gametophyte reaches maturity when sex organs arise on the surface of this sheet of cells. The ontogeny of the gametophyte generation of the tropical fern *Gleichenia bifida*, however, departs from this "typical" progression and apparently represents a new developmental sequence. In this species, initial cell divisions form a 3-dimensional mass of cells from which

the 2-dimensional sheet of cells then develops. It is likely that this course of development represents a response to the type of habitat in which *G. bifida* is found. *Gleichenia bifida* is a colonizing species which is restricted to open, disturbed areas, such as those caused by the frequent landslides which characterize the rainforests of the West Indies and American tropics. These landslides expose large surfaces of bare soil which are subject to rapid soil water depletion due to the loss of the protective canopy. Initial development as a 3-dimensional mass could be an adaptation to survival in exposed habitats since this ontogenetic sequence provides a means of decreasing the evaporative water loss by decreasing the surface to volume ratio of the developing gametophyte.

GROWTH DIRECTION OF THE FIRST BRANCH OF SAGUAROS: ENVIRONMENTAL EFFECTS. J. Patrick Curran, Jodie Zimmerman and Daniel E. Bowen, Biology Department, Benedictine College, Atchison, Kansas 66002.

A common plant on bajadas in the Sonoran desert is the Saguaro Cactus (*Carnegiea gigantea*). This is a tall branching cactus. In older Saguaros the branches are arranged to provide balance. We selected Saguaro cacti with one branch for study because this growth stage of the plant should be most susceptible to problems of balance. The purpose of this paper is to report the tests of the hypothesis that the first branch of all Saguaro cacti point in the same direction. Later we explain the factors that influence this direction. Our research group from Benedictine College made a survey of one-armed cacti in May 1980 at the Saguaro National Monument, Organ Pipe National Monument, and a site just north of San Manual, Arizona. Using compasses we found that 61% of 408 cacti had their single branch facing in a southerly direction ($P < 0.01$).

We speculate that the branch direction is caused by sunlight, or balance, or a combination of the two. We think the greatest factor is the wind because prevailing wind in southern Arizona comes from the south-southeast. There would be much less wind resistance if the branch and trunk are lined up in this direction. The branches may point south to maximize photosynthesis for the bud. But older Saguaros are sensitive to extreme periods of heat and sun, so the shade provided to the trunk by the first branch may be an important factor.

Because the wind and sun both come from the south, separating the importances of these variables is difficult. A test which we propose to do in 1982 is to measure the branch direction of plants growing on steep gully walls. If these branches point south, the sun is most important, if they point in a direction to balance the plant then balance is most important and much of the variation in our data is explained.

HEIGHTS OF WOODPECKERS' NEST HOLE ENTRANCES INTO SAGUARO CACTI. Thomas F. Kemlage, Glenda A. Stark and Daniel E. Bowen, Biology Department, Benedictine College, Atchison, Kansas 66002.

At the turn of the century, two biologists, Charles Bendire and Marshall Gilman, measured the height of nest hole entrances made by Gilded Flickers (*Colaptes auratus*) and Gila Woodpeckers (*Melanerpes uropygialis*) in giant saguaro cacti (*Carnegiea gigantea*). They reported that all nest entrances were from 2.5 m to 13 m off the ground and the most common height was 5 m. The purpose of our study was to repeat the early measurements to see if the preferred height and range of heights have changed after almost one century. In May 1980, a twenty person study team collected data at three sites in the Sonoran Desert. Out of 408 cacti surveyed we found 51 nest holes. No entrances were below 4 m. Most nest holes (29 of 51) were found between 4 m–7 m. The remaining 22 entrances were between the heights of 7 m–9 m. In our study the range of nest hole entrance heights was slightly smaller than in the early study but the preferred height for nest hole entrances remains the same at about 5 m. Reasons for building nests at this preferred height could be that entrances below 4 m are vulnerable to predation by lizards and snakes, while nests above 7 m are susceptible to loss when weakened trees are wind damaged. Nest hole entrances found above 7 m could be there because of competition for nest sites. Some woodpeckers may be forced to build in taller cacti, when the preferred size is less available.

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# Changing Structure of the Beef Industry in Kansas

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ABSTRACT

Fundamental changes have occurred in our society in the post World War II period. These changes have had a great effect on agriculture in general and upon the livestock sector of the economy in particular. The most significant single development in agriculture in Kansas has been the major relocation and expansion of the cattle feeding industry.

In the early 1960's a period of rapid growth and change in feeding began. From an average of 219,800 head on feed in the 1950–1959 period the industry expanded to the marketing of more than 3.4 million head in 1978, ranking Kansas third nationally in production of fed cattle. This rapid growth in volume was accompanied by the emergence of large-scale commercial lots in the High Plains of western Kansas, by the decline of terminal markets, and by a decentralization of packing-house facilities. The forces leading to change in the structure of the cattle industry have assumed many forms and are likely to continue as the industry seeks new adjustments in the future.

A certain nostalgia is present when one contemplates the cattle industry in Kansas. Romantic images of the Old West and the long cattle drives, along such famous trails as the Chisholm, to railheads in Abilene and Dodge City come to mind. Numerous changes have swept our society since this early period, especially in the period since World War II. The population explosion, coupled with regional shifts in population, has not only created a much larger market to be supplied, but has also led to new production and consumption patterns. Incomes and standards of living have increased rapidly. All of these factors have contributed to the changes in the livestock sector of the economy.

Per capita consumption of meat has moved strongly upwards, and beef has accounted for the greater part of this increase (Table 1). Total beef production in the 1970's was more than two and one-half times as great as in 1940. Much more impressive, however, is the trend in cattle feeding and the output of fed beef. More than 13 million head of cattle were on feed in

Table 1. Disposable income and per capita meat consumption (in pounds) in the United States.

| Year | Disposable income | Beef | Veal | Pork | Lamb and mutton | Fish | Poultry |
|---|---|---|---|---|---|---|---|
| 1940 | $ 576 | 54.9 | 7.4 | 73.5 | 6.5 | 10.5 | 16.8 |
| 1950 | 1369 | 63.4 | 7.9 | 69.2 | 4.0 | 11.5 | 24.3 |
| 1960 | 1969 | 85.2 | 6.2 | 65.3 | 4.8 | 10.3 | 34.4 |
| 1970 | 3358 | 113.7 | 5.9 | 65.8 | 3.4 | 11.3 | 42.2 |
| 1975 | 5088 | 120.1 | 4.2 | 56.1 | 2.0 | 16.4 | 49.3 |
| 1978 | 6643 | 120.1 | 3.0 | 61.4 | 1.6 | 17.7 | 57.5 |

Sources: United States Department of Agriculture Technical Bulletin No. 1253, Statistical Bulletin 333, 1970 Supplement, and Agricultural Statistics 1979.

the nation's feedlots on 1 January 1979; whereas, four decades earlier less than three million cattle were being fed for market.

Traditionally the slaughter of cattle for consumption in the United States consisted of grass-fed animals, relatively few of which were fed grain before slaughter. But the modern consumer with a larger disposable income has demanded more uniform grades of meat of higher quality, and as a result drylot finishing has become a vital part of the beef cattle industry.[1]

Historically, the Corn Belt (North Central Region) produced the bulk of fed beef in the United States, but its share has declined relative to other areas in recent years. In the period 1930 to 1939 the North Central Region averaged 80 percent of the cattle on feed; whereas, in 1970 its share had dropped to less than 60 percent. Although the Corn Belt is still an important feeding area, it has lost the degree of dominance it once had, and a major shift to the West has occurred (Table 2).

The High Plains has emerged as one of the nation's leading cattle feeding districts. It is the purpose of this paper to describe the development of present feeding patterns in one of the important states—Kansas—and, to discuss some of the important changes in the overall structure of the livestock industry which have accompanied the rapid expansion in volume of cattle finishing.

## The Farmer-feeder Period

The cattle feeding industry in Kansas dates from the late nineteenth century, and may be divided historically into two major periods. The first period—the farmer-feeder—extends from the inception of the industry into the

[1] The process of drylot cattle feeding involves the confinement of relatively large numbers of cattle in a small area, the drylot, in order to feed them a controlled selection of feeds in such a manner as to obtain the greatest possible weight gains with the least possible cost and time.

Table 2. Number of fed cattle marketed—1978, top ten states.

| State | 1000 head |
|---|---|
| Texas | 4915 |
| Nebraska | 4170 |
| Kansas | 3417 |
| Iowa | 3242 |
| Colorado | 2455 |
| California | 1415 |
| Illinois | 980 |
| Oklahoma | 833 |
| Minnesota | 755 |
| Arizona | 633 |

Source: United States Department of Agriculture Statistical Bulletin No. 522.

1950's and serves as a temporal base for comparing some of the subsequent changes that have taken place, at first slowly and then at an accelerating rate into the present.

A number of physical and cultural conditions contributed to the development of feeding during this early period. Eastern Kansas, located on the Western Margin of the Corn Belt, participated in the general development of this region because there a favorable combination of natural resources in soil, climate, and terrain provided a propitious environment for a mixed farm economy. Initially, the feeding industry was based on roughages—especially alfalfa and corn. As an expanding market for beef developed both regionally and nationally, the concentration of the livestock-slaughter industry at the Kansas City terminal market, as well as at the terminals of St. Joseph and Omaha, was an important factor in the industry's location and expansion. Other factors which aided the development of feeding were the accessibility of feeder cattle from adjacent range areas, the availability of capital from local banks, and adequate transportation facilities for moving cattle from range to feedlot to market. Finally, by providing work for the farmer over the otherwise idle winter season, a more effective use of farm machinery, a dependable market for feed crops and crop by-products available on the average farm, and manure for use in the crop fields, feeding contributed to a balanced farm economy.

The feeding system that evolved can best be described as a complementary-owner-feeder or a farmer-feeder system. Under this system feeders would buy cattle in the fall, about the time their crops were harvested or shortly thereafter, feed the cattle through the winter during the slack season for farm labor, and then market the cattle in the spring before the major cropping work of the spring and summer was undertaken. This type of operation is a part of the total farming operation, the farmer purchasing

cattle to utilize the feed he has produced. Feeding, as it developed in this early period, therefore, was seasonal in nature and comparatively low in capital requirements; and relatively small numbers of cattle were handled or turned out from each individual operation.

## The Commercial Feeder Period

Nationally, a rapid expansion in cattle finishing began during World War II, ushering in the second major feeding period—that of the large scale commercial feeder. The increase in feeding activity was encouraged, in part, by wartime demand for beef and postwar increases in income and population. The large-scale commercial feedlot emerged and now dominates the industry's output.

A comparison between the two major feeding periods reveals some striking differences. First there has been a shift from small-scale seasonal operations to large-scale year-around enterprises. Unfortunately, data on the total number of operations and on the volume of individual operations are not available except for relatively recent years in Kansas. A comparison of data for the decades of the 1930's and 1950's reveals little change in the number of cattle on feed. Kansas feeders in the 1930's averaged 208,000 head on feed January 1 but in the 1950's averaged 219,000 head. A 1957 Kansas State Agricultural Experiment Station Bulletin, *Kansas Agriculture After 100 Years,* provides only a limited amount of information on the State's livestock industry, which is somewhat surprising since the marketing of livestock and livestock products accounted for over one-half of the State's farm income. The study, using 1954 census of agriculture data, notes that ". . . 85.4 percent of all farms in the state reported cattle and calves, with rather wide variation in the number per farm reporting." This variation ranged from 93 in the Clark, Comanche, Barber County region—predominantly range livestock—to 26 in the six southeastern counties. While this data mask many differences in the State's livestock industry they do point up the nature of the industry's small scale in this period.

In the 1962–63 Kansas State Board of Agriculture, *Farm Facts,* for the first time information on cattle on feed is presented (Fig. 1). It is observed that "The total inventory value of all cattle and calves on January 1, 1963, was $715 million, up 8 percent from a year earlier. Included in the January 1, 1963, inventory were 392,000 head of cattle and calves on feed for slaughter market. This was 13 percent more than the 347,000 head on feed a year earlier, and the largest of record. Of the total number on feed January 1, 1963, 242,000 head were being fed in farm feedlots, down slightly from a year ago, and 150,000 head were in commercial feedlots, up 52 percent from January 1, 1962."

The 1965–66 *Farm Facts* states that "There were some very sharp and complex changes in cattle feeding operations recorded during 1965. For the

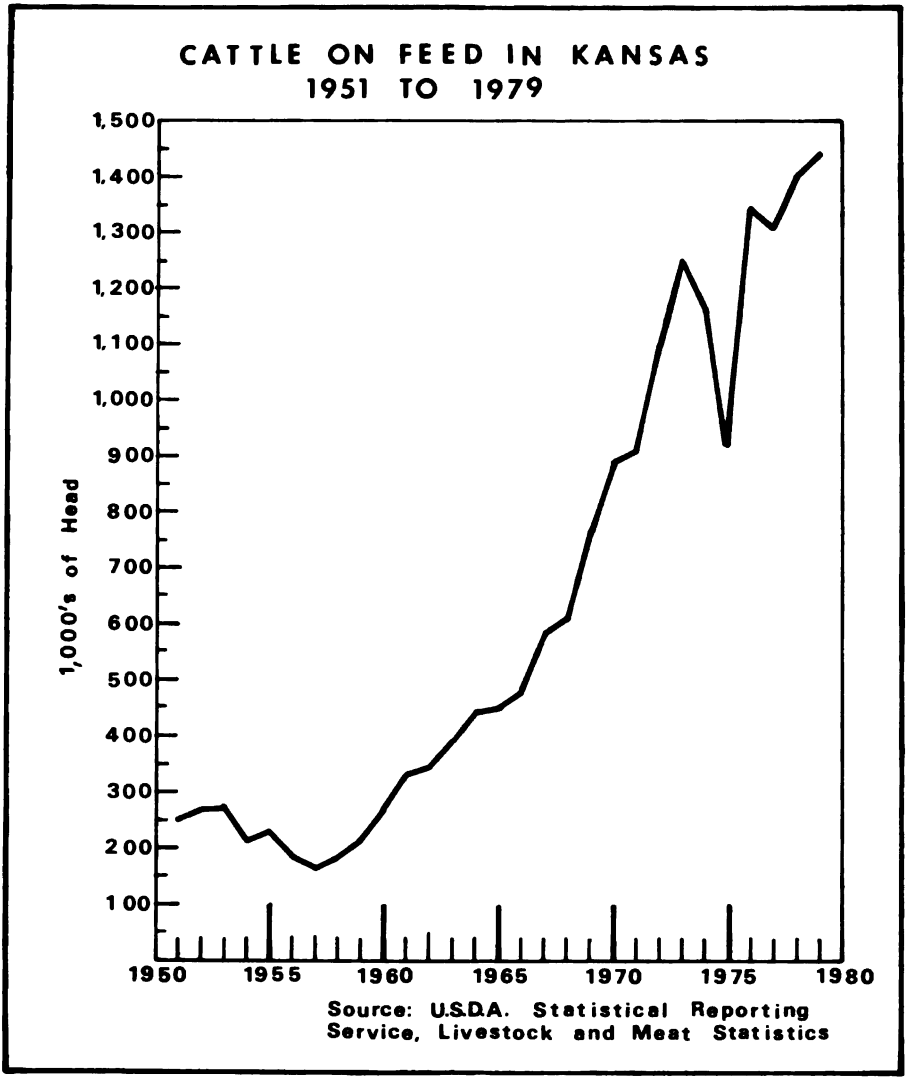


Fig. 1

first time, large feedlots with over 1,000 head capacity accounted for more than half of total cattle and calves on feed in all quarters of the year. . . . Farm feeding operations declined while large feedlot operations continued to grow and reach record high levels. . . . By January 1, 1966, farm feeding was still at a level below the previous year and considerably below the average of the previous five years. Cattle on feed in large commercial feed-

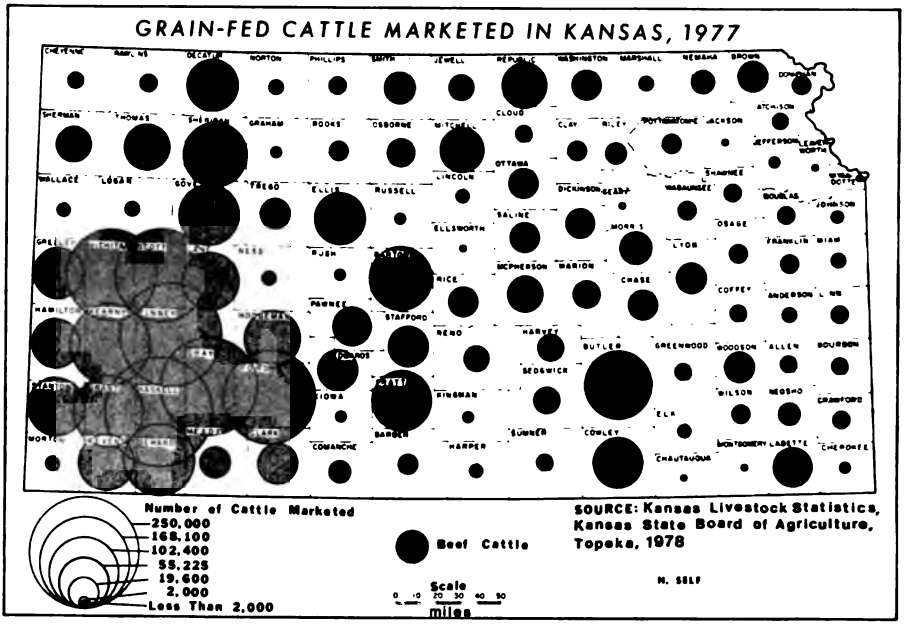


Fig. 2

lots were at a record level, more than twice the 1960–64 average." Since the mid 1960's, data on the number and size of feedlots in Kansas have been published by the United States Department of Agriculture. An analysis of this data reveals that during the period from 1965 to 1978 the number of small feedlots (under 1000 head capacity) in Kansas decreased from 13, 412 to 5331. During this same period the number of large-scale commercial feedlots increased from 88 to 169. The total number of feedlots has declined and probably will continue to do so, but at a slower rate than in earlier years. Of much greater significance, however, is the fact that the number of feeders with feedlot capacities of more than 1000 head has increased appreciably over the last decade and a half.

In the decade from 1950 to 1959 Kansas averaged 219,000 head of cattle on feed. In 1978, 3,471,000 head of cattle were marketed from the state's feedlots, and Kansas accounted for nearly 8 percent of the cattle fed nationally. Large-scale commercial feedyards accounted for 82 percent of this total.

The emergence of the commercial feeder and the expansion in the volume of cattle finishing have been accompanied by substantial changes in the overall structure of the industry. Although the basic objective in cattle feeding remains the same—to transform feed and cattle into finished beef in the most profitable manner possible—the patterns of procurement of resources

Table 3. Livestock shipped into Kansas by state of origin, 1978.

| State of origin | Number of head |
|---|---|
| Oklahoma | 853,700 |
| Missouri | 538,900 |
| Texas | 485,900 |
| Kentucky | 266,500 |
| Arkansas | 175,600 |
| Tennessee | 115,900 |
| Mississippi | 97,700 |
| Colorado | 91,000 |
| New Mexico | 80,900 |
| Alabama | 75,000 |
| Nebraska | 72,000 |
| South Dakota | 49,500 |
| Louisiana | 38,300 |
| Illinois | 32,100 |
| Wyoming | 30,100 |
| Other states and Canada | 146,900 |
| TOTAL | 3,150,000 |

Source: Kansas Crop and Livestock Reporting Service, Kansas Livestock Statistics 1977–1978.

used in feeding and the location of feeding today are markedly different from those of the farmer-feeder period. The development of commercial feeding has centered in the High Plains region of western Kansas, and the bulk of fed cattle produced today come from this region (Fig. 2).

The first resource component essential to the development of a feeding industry is the availability of feeder cattle, and Kansas has long been noted as a quality producing area. In the period prior to World War II local cattle played a dominant role in the state's feedlots, and one might reasonably expect that with large numbers of quality cattle in relatively close proximity to western Kansas the same relationship would hold in the present period; however, such is no longer the case. Despite the increased production of beef calves over the last decade, Kansas has become increasingly dependent on outside areas for its supply of feeder cattle (Table 3).

The expansion of year-around feeding has led to a demand for feeder cattle throughout the year, but often cattle cannot be obtained locally when they are needed. This lack of local cattle has necessitated an expansion of the supply area and the import of additional cattle to augment these available locally. Because Kansas is centrally located in relation to major surplus producing states, the availability and cost of cattle should not prove to be a limiting factor in the continued expansion of the feeding industry.

At the turn of the century information on livestock feeding and animal

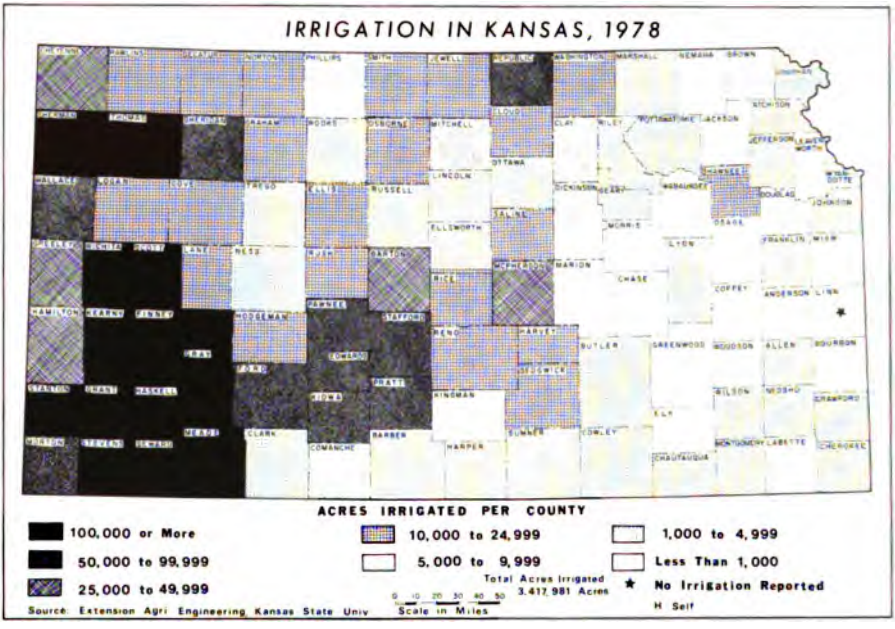


Fig. 3

nutrition was exceedingly limited. Hormones, vitamins, antibiotics, and trace minerals were entirely unknown. Experimental results were limited, and nutritional data were fragmentary; consequently, largely out of necessity, feeding was based mainly on the experience of successful feeders. But in the last decade or two, nutritionists and feeders have increased considerably their scientific knowledge concerning balanced rations and efficient procedures for feeding cattle. Although the nutritional requirements of cattle are rather clearly defined within certain maximums and minimums, each feedlot has a different set of conditions depending on such factors as the materials-handling system utilized, which eliminates some feeds; the type and weight of cattle; the economics of the feeds available; and likes and dislikes of the feeder. Therefore, there is great variability in the rations utilized from operation to operation. But the result of these improvements is that cattle are finished at a younger age and at lighter weights with less excess fat.

All of these developments have been accompanied by changing composition in the various rations fed. In general, feeders have shifted to using higher energy feeds. Today the typical ration would be composed of 50 to 60 percent roughage, of 30 to 40 percent grain, and 5 to 10 percent of the ration would include a protein supplement, other high energy feeds, and various additives.

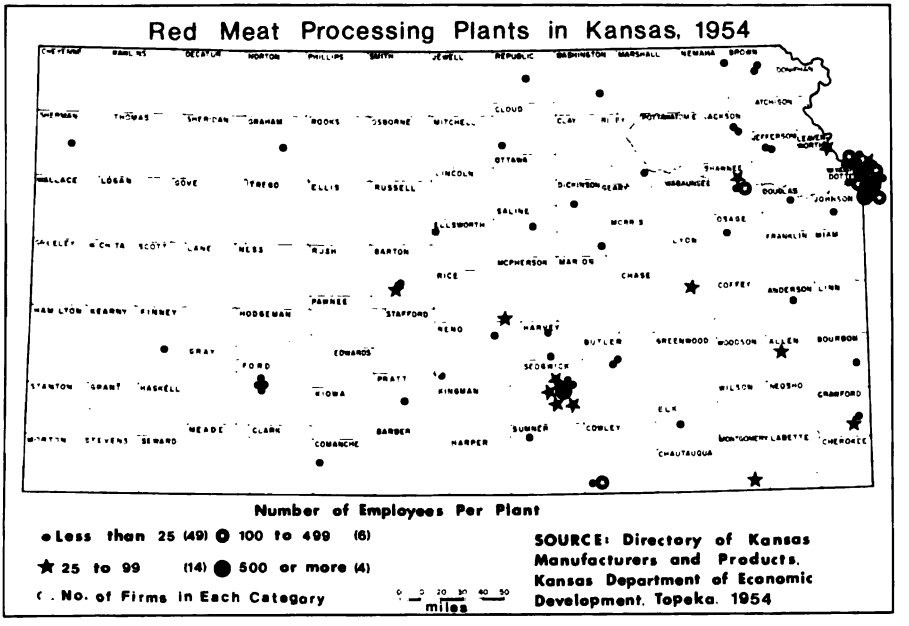


Fig. 4

Kansas is fortunate in having the second major resource essential to the development of a feeding industry, a highly diverse feed resource base. The availability of a high quality roughage supply was a major factor in the development of feeding in the farmer-feeder period. In recent years roughage availability has continued to play a major role, and with the rapid development of irrigation, production has continued to increase. In 1950 just over 200,000 acres were irrigated; by 1978 over 3,100,000 acres were under irrigation (Fig. 3). A comparison of the map on grain fed cattle marketed in Kansas with that of irrigation patterns reveals a strong correlation between the leading counties in commercial feeding and irrigation. Today approximately three-fourths of the total roughage requirement is composed of silage, while the other one-quarter is made up of hay. Because of its bulky nature, roughage cannot be moved any great distance economically; this has been a major factor in the localization of feeding.

In recent years grain too has taken on more importance in cattle feeding rations. Corn and sorghum account for the bulk of the grain consumed in the state's feedlots, but lesser amounts of wheat, oats, rye, and millet are fed as well. Kansas has had a net surplus in feed grain production in the past decade and the state is favorably situated in relation to other major surplus production areas in the Great Plains. Feed grains have been, are,

and will likely continue to be abundant for the cattle feeders of the High Plains. Overall it appears that Kansas has a highly diverse feed resource base. Feed availability should not prove to be a limiting factor in the future expansion of cattle feeding.

The changes from small-scale seasonal operations to large-scale year-around enterprises, from an industry based on local resources to an individually owned income-supplementing farm operation to corporate "beef factories," and from the philosophy of "The eye of the master fatteneth his cattle," and adage held by feeders, to that of scientific research and technology supplementing the "eye of the master" in the commercial operation of the 1970's, have been coupled with changes in other sectors of the industry.

## Market Outlets and Meatpacking

In the latter part of the 19th century the nation's railroad system expanded rapidly and pushed West to tap the cattle country. Railroad development precipitated a shift from cattle drives and water transportation to rail transportation and facilitated the assembly of livestock in large numbers in a few relatively large cities situated at key transportation nodes. This geographic concentration of cattle led to the development of extensive stockyard facilities, and the central or terminal market emerged. Terminal yards were organized at Kansas City in 1871, Omaha in 1884, and St. Joseph in 1896 (Fowler, 1961).

Meat packers, attracted by the concentration of livestock, developed slaughter plants—many of large size—adjacent to the terminal stockyards. The essentials of the terminal market system that developed between the Civil War and World War I are: 1) one corporation, the stockyards company, which owns the physical facilities for handling and caring for livestock; 2) commission agents who handle the various market transactions, although anyone has the privilege of buying or selling; and 3) nearby packing houses which convert large numbers of slaughter animals into meat and meat products (Anthony and Motes, 1966).

The development of a centralized marketing system was the result of the transportation and communication patterns that evolved about the turn of the century. Refrigerator cars, an innovation in the 1860's, made possible rail transportation of fresh meat over long distances. Consequently, slaughter could take place at terminals far removed from consuming markets. This basic, highly centralized pattern, remained substantially unchanged until after World War I when many factors combined to reduce the advantages derived from the concentration of livestock and slaughter facilities at the terminal public markets. This national trend toward decentralization of marketing and slaughter has accelerated in recent years, the shift in Kansas being most notable since the late 1950's.

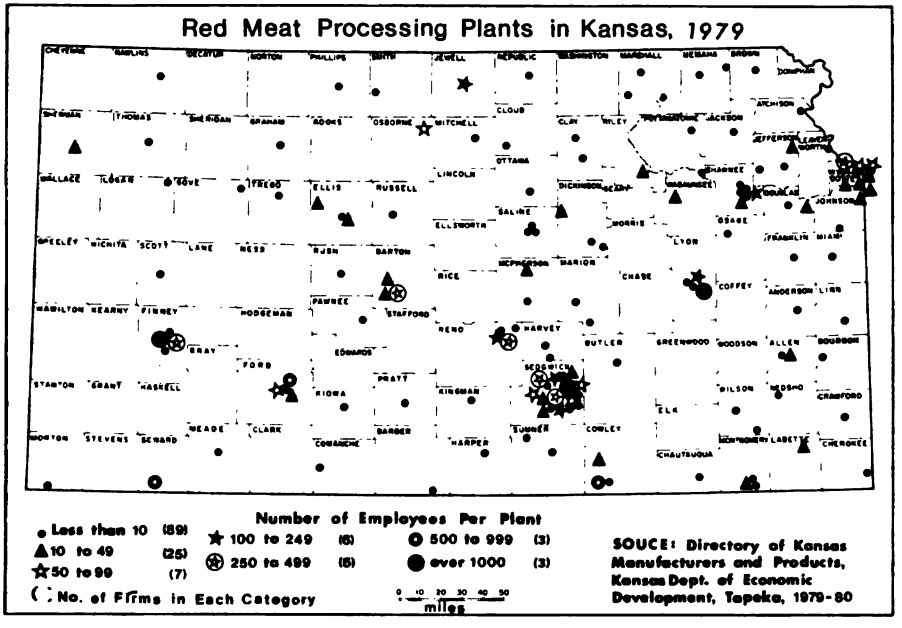


Fig. 5

Foremost among the developments leading to a movement away from the terminal market has been the improvement in motor trucks and the vast expansion of hard-surfaced highways. The economy, speed, and flexibility of truck transportation have opened up new directions of movements and new market outlets for cattle.

Other important factors which have combined with truck transportation to reduce the importance of the terminal are: 1) changes in the channels through which livestock move to market, especially the development of auction markets and direct marketing; 2) an increasing proportion of slaughter performed by meatpackers located away from terminal markets; 3) traffic congestion in metropolitan areas around terminal markets, making them less convenient for the livestock producer; and 4) improvements in market news coverage and communication, thereby reducing the importance of close contact with the terminals for essential market intelligence (Anthony and Motes, 1966). Although the terminal market has declined in importance, it has not disappeared. In the 1940's yearly cattle runs of up to 8 million moved through the Kansas City market, but by 1978 only 375,000 head, mostly feeder cattle, were marketed.

In Kansas, the manner in which fed cattle are marketed has changed significantly since the early 1950's. In 1978 of all cattle purchased by packers only one percent was at the terminal market. Increased direct sales—from

feedlot to packer—have been a major factor in the decline of the terminal market.

The increase in direct marketing has come about for several reasons. In the terminal market system the seller bears all costs, including transportation, shrinkage, feed, and commission fees, until the cattle are sold. In addition, the consignment of cattle to a terminal is, in effect, an almost irreversible commitment to sell; and the seller, once the cattle are at the terminal, has little control over what takes place. Direct selling allows the producer to exercise a greater degree of control over the sale of his cattle, and not only offers greater convenience, but also reduces the risk of price changes.

Another reason that the shift to direct marketing has come about is that packers desire a relatively uniform quality of slaughter cattle and need a reasonably constant supply. Commercial feeders are able to meet this demand because they market frequently and in substantial quantities. Both the feeder and the buyer become relatively well acquainted and are able to bargain effectively on sales, and each thereby complements the other's needs.

The decentralization of live marketing has been accompanied by a parallel development in the meat packing industry. In brief, the movement of packing away from the terminal markets has been an attempt to offset certain disadvantages and to gain certain advantages. The major goals have been: 1) to gain greater efficiency in transportation; 2) to gain a more favorable labor position; 3) to gain the advantages of proximity to producers; 4) to eliminate the high costs of obsolete packing-house facilities, replacing them with more efficient, newer, modern plants; and 5) to eliminate the high costs associated with terminal congestion (DeGraff, 1960). These factors have altered the structure and organization of the meatpacking industry in Kansas.

The location of plants within Kansas has shifted because in today's economy the requirements for location have changed. Highway transportation makes it possible to assemble an adequate supply of livestock and to ship meat from non-terminal points. Through plant modernization, the output per unit of labor has been reduced; so plants no longer need to be located in a large city near a concentrated labor supply. Power sources—adequate fuel and electricity—are also available at most sites. Because of improvements in communication facilities the flow of information is rapid and readily available at any location. Consequently, meatpackers no longer need to be at the terminal market points. As a result, new plants are generally not being built at terminals, and non-terminal slaughter is increasing. Thus, the reorientation of slaughter location, both nationally and regionally, is away from centers of consumption and toward points of production.

In 1954 there were 79 red meat processing firms in Kansas (Fig. 4). *Four-*

*teen* of these firms were located in Kansas City, including 7 of the 9 largest operations in the state, hiring from 100 to over 1000 employees. By 1979 the number of firms had increased to 114 and had become widespread across the state. In Kansas City only 8 remained and of these only one hired more than 250 employees (Fig. 5).

The Iowa Beef Processors' projected new plant near Garden City exemplifies the recent trend to locate near the source of supply. When in full operation, sometime in 1984, the plant will employ approximately 2000 persons and be capable of processing about 1.2 million head of cattle per year. This in turn will stimulate the feeding industry in the High Plains of western Kansas and the surrounding region.

Cattle feeding in Kansas has undergone a period of extensive change in the last two decades and the High Plains has become one of the nation's most important feeding centers. The large-scale commercial lot emerged in the early 1960's, and today over 80 percent of Kansas fed beef is produced in these operations. Because the development of commercial feeding has led to the creation of individual feedlot slaughter cattle markets, terminal markets have declined in importance. Decentralization of marketing has been coupled with decentralization of packing. It is expected that large-scale, highly mechanized, commercial operations, with capacities for feeding several thousand head will continue to be a major force in the agricultural economy of Kansas.

## Literature Cited

Anthony, Willis E., and William C. Motes. 1966. "Livestock Marketing," Agricultural Markets in Change. Economic Research Service, United States Department of Agriculture, Washington, D.C. Agricultural Economic Report No. 95. pp. 265–269.

Beaton, Norman J., and John H. McCoy. 1970. Economic Characteristics of Kansas Livestock Auctions. Agricultural Experiment Station, Kansas State University of Agriculture and Applied Science, Manhattan, Kansas. Bulletin 537. pp. 1–11.

Brimyer, Harold F. 1961. Demand and Prices for Meat, Factors Influencing Their Historical Development. Economic Research Service, United States Department of Agriculture, Technical Bulletin No. 1253. Government Printing Office, Washington D.C. p. 47.

DeGraff, Herrell. 1960. Beef Production and Distribution. University of Oklahoma Press, Norman. pp. 68–93.

Duddy, Edward A. 1954. "The Place of Terminal Markets," Marketing. The Yearbook of Agriculture, Government Printing Office, Washington, D.C. pp. 37–48.

Gurss, Gerald D. 1978. Annual Report of Public Livestock Markets in Kansas. Kansas Animal Health Department, Topeka, Kansas. pp. 1–11.

Hoover, Leo M. 1957. Kansas Agriculture After 100 Years. Agricultural Experiment Station, Kansas State College of Agriculture and Applied Science, Manhattan, Kansas. Bulletin 392. pp. 1–65.

The Kansas City Stock Yards Company. 1946. 75 Years of Kansas City (Missouri) Livestock Market History. pp. 1–40.

Kansas Crop and Livestock Reporting Service. Farm Facts. Kansas State Board of Agriculture cooperating with United States Department of Agriculture, Annual Reports 1950–1979, Topeka, Kansas.

Kansas Crop and Livestock Reporting Service. Kansas Livestock Statistics 1978–1979. Kansas State Board of Agriculture cooperating with United States Department of Agriculture, Topeka, Kansas. pp. 1–32.

Kansas Department of Economic Development. 1979. Report. Volume 15, Number 5, p. 1, and Volume 16, Number 10, p. 1, Topeka, Kansas.

Kansas Department of Economic Development. 1979. Directory of Kansas Manufacturers and Products, Topeka, Kansas. pp. 200–202.

United States Department of Agriculture. 1969. Livestock-Feed Relationships 1909–1963. Supplement for 1968. Economic Research Service, Statistical Bulletin No. 337. U.S. Government Printing Office, Washington, D.C. pp. 1–37.

United States Department of Agriculture. 1979. Agricultural Statistics. United States Government Printing Office, Washington, D.C. pp. 352–353.

United States Department of Agriculture. 1979. Livestock and Meat Statistics, Supplement for 1979, Economics, Statistics, and Cooperatives Service, Agricultural Marketing Service, Statistical Bulletin No. 522. pp. 1–103.

United States Department of Agriculture. 1979. "Packers and Stockyard Resumé." Packers and Stockyards Administration, Agricultural Marketing Service, Washington, D.C. pp. 1–33.

Uvacek, Edward, and D. L. Wilson. 1959. Livestock Terminal Markets in the United States. United States Department of Agriculture, Marketing Research Report No. 299, pp. 1–13.

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# A Dipnoan Tooth Plate from the Lower Cretaceous of Kansas, USA

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ABSTRACT

For the first time, a dipnoan tooth plate is described from the Lower Cretaceous (Kiowa Formation) of Kansas. The pterygoid tooth plate is referred to *Ceratodus frazieri* Ostrom, 1970. The histology shows anomalies in the formation of the tooth plate, osteodentine occurring within petrodentine. *Ceratodus* is an additional indication of freshwater influence in the marine Kiowa Formation deposits.

Fossil vertebrates have been collected in Cretaceous rocks of western Kansas by members of the University of Kansas and parties of many other universities and museums during more than 100 years. The marine Niobrara Chalk, Upper Cretaceous, is the formation preferred by many for collecting. Fossil vertebrates are scarce and not as well preserved in the more terrestrially influenced Lower Cretaceous. The upper unit of the Lower Cretaceous in this area, the Dakota Formation, is known for its plant content, and has yielded very few vertebrate remains. The armoured dinosaur *Silvisaurus* (Eaton, 1960) indicates terrestrial environment, the crocodile *Dakotasuchus* and tracks referred questionably to crocodiles (Vaughn, 1956) indicates coastal environment, and one known plesiosaur (Sternberg Memorial Museum, Hays, Kansas) signifies a marine environment for the Dakota Formation. The present interpretation of the depositional environment of the Dakota Formation is that of a coastal plain with low relief in central Kansas and a shallow, epicontinental sea in western and southern Kansas (Scott, 1970). The Kiowa Formation underlies the Dakota Formation, but both formations may interdigitate at their boundary. The fossil remains, invertebrates and most vertebrates (all partial: plesiosaurs, selachians, and actinopterygians, Scott, 1970: Table I), indicate a marine environment for the Kiowa Formation.

M. Williams, a former student at the University of Kansas, found one lungfish tooth plate (KUVP 16262 mentioned by Chorn, 1977) in the Kiowa Formation in Clark County, Kansas, 1969. Lungfish tooth plates in late Mesozoic and Cenozoic deposits are normally interpreted as an indicator of

freshwater. They are found together with dinosaur remains, goniopholid crocodiles and turtles in the Lower Cretaceous, Aptian-Albian, Cloverly Formation of Wyoming (Ostrom, 1970), Paluxy Formation of the Trinity Division of Texas (Thurmond, 1974), and in the Lower Cretaceous, Aptian-Albian, of Northern Africa (Tabaste, 1963; Taquet, 1970; Broin, Grenot and Vernet, 1971). These indicators of terrestrial conditions (very few dinosaur remains, goniopholid crocodiles, and carapace remains of presumably baenoid turtles) are also known from the Kiowa Formation (Scott, 1970: Table 1). These remains, together with the lungfish tooth plate, must be interpreted as allochthonous within the marine community; they have drifted in from a not too distant shore.

Since Agassiz (1833–44), isolated ceratodontid tooth plates of Mesozoic and Tertiary age have been referred to the genus *Ceratodus*, although it is known that the tooth plates do not reflect generic differences (Peyer, 1918). Skull roofs of Mesozoic lungfishes with ceratodontid tooth plates are so distinct from each other that they have been referred to new genera (*Paraceratodus* Lehman, Chateau, Laurain and Nauche, 1959; *Asiatoceratodus* Vorobyeva, 1967; *Tellerodus* Lehman, 1976; *Arganodus* Martin, 1979). All these genera have ceratodontid tooth plates with sharp-crested ridges, while no skull roof with flat tooth plates as in the type species *Ceratodus latissimus* Agassiz 1838 has yet been described. Even *Ceratodus* is a form genus for Mesozoic and Tertiary tooth plates; it is at present the best way to determine ceratodontid tooth plates which are not associated with skull roof material.

In the Lower Cretaceous, flat ceratodontid tooth plates and ceratodontid tooth plates with sharp-crested ridges occur together in the Lower Cretaceous of Northern Africa (Tabaste, 1963; Martin, 1979). In the Lower Cretaceous of North America, only two flat ceratodontid tooth plates are known, one from the Cloverly Formation, Wyoming (*C. frazieri* Ostrom, 1970) and a partial one from the Morrison Formation, Wyoming (*C. robustus* Knight, 1898). All other North American ceratodontid tooth plates (*C. guentheri, C. americanus*) of Lower Cretaceous age have sharp-crested ridges and are therefore not comparable to the Kiowa tooth plate.

Recently, many papers on the histology of lungfish tooth plates have been published (Denison, 1974; Smith, 1979; Kemp, 1979; and others). The authors differ in their terminology of the hard tissue, and the terminology of Smith (1979) is used here. Tabaste (1963) described and figured a special tissue as "tissue osteoide" which forms small grooves on the surface of the tooth plates. There exists no agreement on the nature of this tissue, therefore lungfish tooth plates from the Lower Cretaceous of Africa are investigated here for clarification and as comparison with similar structure on the Kiowa tooth plate.

*Ceratodus frazieri* Ostrom, 1970

*Holotype*. Left prearticular tooth plate YPM 5276 (Peabody Museum, Yale University).

*Horizon/Locality*. Cloverly Formation, Albian, Lower Cretaceous/approximately 75 m southeast of Princeton University locality 49-1; NW ¼ Sec. 34, T58N, R75W, Big Horn County, Wyoming.

*Diagnosis*. (Ostrom, 1970, p. 54) "Dental plate very large, broad and thin with four broad and apparently non-tuberculated radial ridges. The ridges are not sharp crested distally as in *C. guentheri*, nor do they extend to the medial margin of the plate. Externally, these ridges end in broad projections separated by shallow notches. Anterior ridge, the largest, ends in the longest distal projection. Posterior ridge very faint, terminates distally in a very slight lateral projection. These radial ridges so subdued, apparently by excessive wear, that the typical ceratodontid radiation pattern is not clear, except near the external margin. Internal margin broadly rounded and not angled as in most other ceratodontids."

*Material from Kansas*. One right pterygoid tooth plate with part of the pterygoid (KUVP 16262, Museum of Natural History, Lawrence, Kansas) from 6 miles north of Sitka (near the center of Sec. 18, T32S, R21W, Clark County, Kansas)/Kiowa Formation, Lower Cretaceous.

*Description*. The large tooth plate (maximal width 32 mm, maximal length approximately 60 mm or more; greatest thickness 6.5 mm) is attached to the partially preserved pterygoid bone. The surface of the tooth plate shows irregularly arranged circular fields (Fig. 1a) reflecting a change in tooth histology (see below). The tissue forming the boundary of the circular fields is softer than the surrounding tissue so that narrow furrows are formed. Small pits on the ventral surface (Fig. 1b: right side) correspond to the circular fields on the occlusal surface. There are two possible explanations for these pits: the hard tissue was not mineralized or it was so soft that it has been eroded away.

The tooth plate is flat. Four low ridges occur near the buccal margin only, and a fifth ridge is weakly developed. The valleys between the ridges are very shallow, nearly undifferentiated from the main occlusal surface. The first ridge—as far as can be judged from the preserved portion—extends nearly parallel to the medial margin and forms an angle of 45° to the second ridge. The crests of the following 3 ridges are parallel to each other, and the fifth very shallow ridge is oblique to the fourth. The medial margin forms an obtuse angle with the lingual margin, and the lingual margin with the posterior one. The medial and posterior margins include an angle of about 90°.

The inner surface of the tooth plate is nearly planar so that the thickness of the plate varies, being thicker below the ridges.

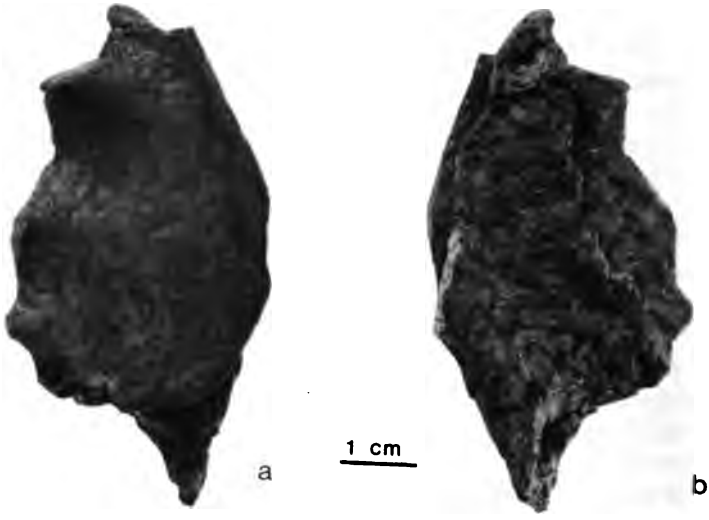


Fig. 1. Right pterygoid tooth plate KUVP 16262 of *Ceratodus frazieri* Ostrom, Kiowa Formation, southern Kansas. a. palatal view; b. dorsal view.

Only a portion of the pterygoid (Fig. 1b) is preserved, which is attached to the tooth plate on the posterior and presumably also along the anterior border. The subdentinal cavity between the tooth plate and the pterygoid is filled by rock and celestine. The lingual border extends parallel to the mesial and lingual margins of the tooth plate and curves laterally as the posterior border of the tooth plate (angle of 140°). The postero-lateral flange and the lateral portion of the pterygoid are missing.

*Histology*. The tooth plate of *C. frazieri* from the Kiowa Formation is that of an adult individual. As noted above, the irregularly arranged circular fields on the occlusion surface and the shallow pits on the inner surface to the subdentinal cavity (Smith, 1979) indicate differences in the composition of the tooth plate. These irregularly arranged circular fields can be found in many other *Ceratodus* tooth plates; they have been described by Tabaste (1963). For comparison with the Kiowa tooth plate, tooth plates with similar structures of about the same age from northern Africa (Tabaste, 1963) were sectioned (Fig. 2). The tooth plate is formed by petrodentine, a secondary dentine with vertical pulp canals (term of Lison, 1941, usage after Smith, 1979 = "tubular dentine" of Denison, 1974 = "central dentine" of Kemp, 1979). Petrodentine is the main hard tissue which forms *Ceratodus* tooth plates and *Sagenodus* tooth plates in the Carboniferous (Smith, 1979). Circumpulpal dentine surrounds the pulp canals, this dentine with dentine tubules is not as highly mineralized as the petrodentine and thus darker stained

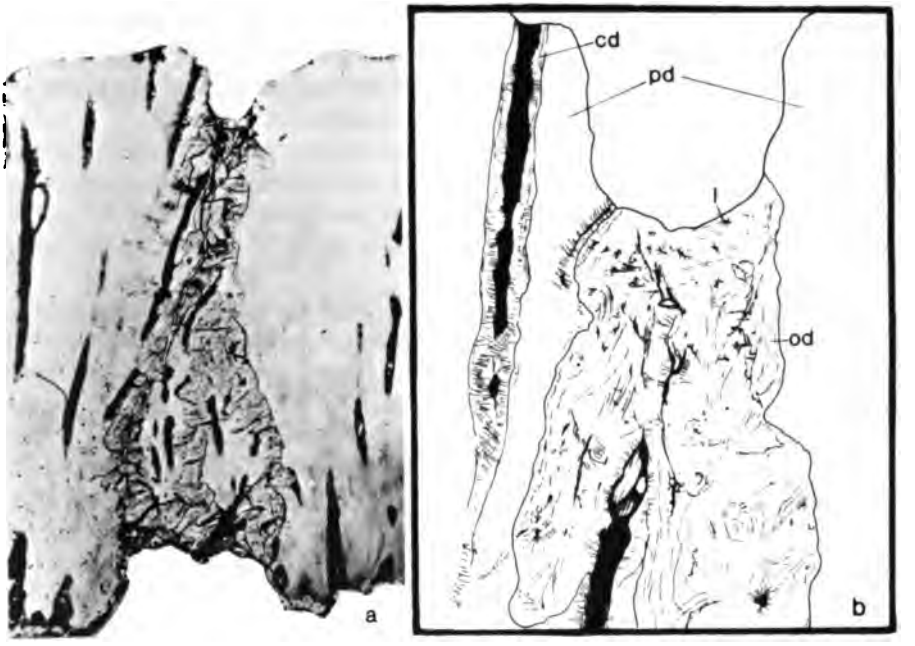


Fig. 2. Vertical thin section (labial-lingual KUVP 60651b) of pterygoid tooth plate of *Ceratodus africanus* from the Lower Cretaceous of Northern Africa. a. middle part of the section with osteodentine, b. upper part from a: cd = circumpulpal dentine, lb = lacunae of bone cells, od = osteodentine, pd = petrodentine.

by the process of fossilization. It is softer than the petrodentine, and is more easily eroded than the surrounding petrodentine. A different tissue even softer than the circumpulpal dentine is responsible for the circular fields and the deeper grooves on the occlusal and inner surface. This tissue is stained more during fossilization than is the circumpulpal dentine, showing that it contained even more organic substance. Many lacunae of bone cells are visible in that tissue. The pulp canals penetrating this tissue branch off in many narrower branching canals. The tissue around the branching canals has dentine tubules; these are denteons (Ørvig, 1951). That agrees with the determination of this tissue as "tissue osteoide" by Tabaste, 1963 (p. 446, plate 4, figs. 2, 3) while Kemp, 1979 uses the term "secondary mesenchymal matrix" for hard tissue in *Neoceratodus* situated like this tissue around branching pulpal canals; he considers it as dentine because he could rarely observe bone cells. Denison (1974) calls the same tissue at the margin of the tooth plate of *Neoceratodus* "new dentine." Field Museum slide 5513 (Denison, 1974, fig. 9) shows lacunae of bone cells in that tissue (perhaps the "pleromic dentine" of Smith, 1979, Fig. 14 is the same tissue). The

boundary between petrodentine and osteodentine is irregular and seems to point to resorption of petrodentine before deposition of the osteodentine (Fig. 2b). The grooves on the inside of the tooth plate of *C. frazieri* and of the African *Ceratodus* could support such suggestions.

The occurrence of irregular circular fields or grooves in *Ceratodus* tooth plates is the result of enclosure of marginal osteodentine, as occurs in *Neoceratodus*. The marginal osteodentine is not completely replaced by petrodentine, and the tissue continues to grow like the petrodentine on the inner side of the tooth plate.

*Comparison*. The tooth plate from the Kiowa Formation belongs to the forms of *Ceratodus* characterized by flat tooth plates without sharp-crested ridges. Similar flat tooth plates occur in the Lower Cretaceous of Northern Africa, but some of these species (*C. africanus*, *C. pectinatus*, *C. tuberculatus*) have a higher number of ridges on the tooth plate (6–7, 8–9, 6), the ridges are more pronounced, their tooth plates are more elongated, and their inner margin is not angled twice as is *C. frazieri* from the Kiowa and Cloverly formations. The tooth plate of another African species, *C. humei* (Tabaste, 1963, pl. 2, figs. 1, 2), has a low number (4) of ridges as does the specimen from the Kiowa Formation. The shape of the tooth plate is similar but with a marked difference: a ridge corresponding to the first ridge in the tooth plate from the Kiowa Formation is not developed so that medial and lingual margins form a less obtuse angle in *C. humei*.

The prearticular tooth plate of *C. frazieri* Ostrom, 1970 from the Lower Cretaceous Cloverly Formation agrees closely with the Kiowa example in the number of ridges (4—one less than the pterygoid plate as is the normal case) and in the shape of the inner margin. Both tooth plates are superimposed (Fig. 3) (broken line = prearticular plate from Cloverly Formation, solid line = pterygoid plate from Kiowa Formation). The ridges of one plate fit into the valleys of the other, even though the specimen from the Kiowa Formation is a little larger. The only other comparable tooth plate, the fragmentary pterygoid tooth plate (I agree with Ostrom, 1970 that the specimen is a pterygoid tooth plate rather than a prearticular tooth plate) of *C. robustus* (Knight, 1898) presumably from the Morrison Formation of Wyoming, is difficult to compare. The shape of the inner margin does not correspond, and the posterior crests are more pronounced. Better material is needed to show that *C. robustus* is closely related to *C. frazieri*. The description of the *Ceratodus* tooth plate from the Paluxy Formation of Texas (Thurmond, 1976, p. 107) suggests comparison with *C. americanus* in having distinct ridges, a feature quite different from *C. frazieri*. The close approximation of the 2 posterior ridges (not the anterior ones as described by Thurmond, 1976) is another feature which distinguishes *C. americanus* from *C. frazieri*. *Ceratodus* tooth plates from the Trinity Division of Texas

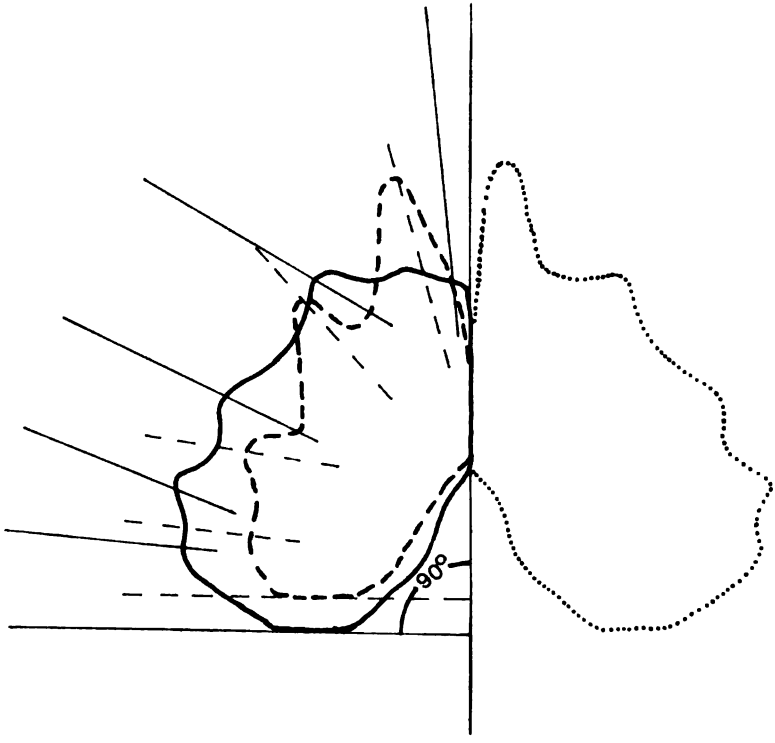


Fig. 3. *Ceratodus frazieri* Ostrom: Pterygoid tooth plate KUVP 16262 (solid line) from the Kiowa Formation, Kansas, superimposed on prearticular tooth plate YMP 5276 (broken line, after Ostrom, 1970, pl. G, Fig. A) from the Cloverly Formation, Wyoming.

in the Field Museum of Natural History, Chicago, agree with Thurmond's description as mentioned by Thurmond, 1974 (p. 107). They differ from *C. frazieri* in the above mentioned features.

All tooth plates compared above with *C. frazieri* from the Kiowa Formation occur together with terrestrial tetrapods, while the Kansas specimen occurs as a "stray" in the epicontinental sea of the Lower Cretaceous of Kansas.

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## Literature Cited

Agassiz, L. 1833–44. Recherches sur les Poissons Fossiles. 5 vol., vol. 1: I–XLIX, 1–188, pl. A-K; vol. 2: I–XII, 1–310, pl. A–J, 1–75; vol. 3: I-VIII, 1–390, pl. A–S, 1–47; vol. 4: I–XVI, 1–269, pl. A–L, 1–44; vol. 5: I–XII, 1–122, pl. A–M, 1–64; (Petitpierre), Neuchâtel.

Broin, F. de, C. Grenot, and R. Vernet. 1971. Sur la découverte d'un nouveau gisement de Vertébrés dans le Continental Intercalaire saharien: la Gara Samani (Algérie). C. R. Acad. Sci. Paris, 272, Sér. D.:, 1219–1221, 1 fig.

Chorn, J. 1977. Fossil lungfishes in Kansas. Trans. Kansas Acad. Sci. 79:95–96.

Denison, Robert H. 1974. The structure and evolution of teeth in lungfishes. Fieldiana, Geology, 33, Nr. 3:31–58, 15 figs.

Eaton, T. H. 1960. A new armored dinosaur from the Cretaceous of Kansas. Univ. Kansas Paleont. Contrib., Vertebrata, AA 8, 24 pp., 21 figs.

Haug, E. 1904. Sur la faune des couches à *Ceratodus* crétacées du Djoua, près Timassânine (Sahara). C. R. hebdom. Séanc. Acad. Science. 138:1529–1531.

Kemp, A. 1979. The histology of tooth formation in Australian lungfish, *Neoceratodus fosteri* Krefft. Zool. J. Linnean Soc. 66:251–287.

Knight, W. C. 1898. Some new Jurassic vertebrates from Wyoming. Amer. J. Sci., ser. 4, 5:76, 2 figs.

Lehman, J.-P. 1976. A propos de *Ceratodus sturii* Teller, 1891. Bull. Mus. Nat. d'Hist. Natur. Paris, 3 sér., No. 375, 1975:241–246.

Lehman, J.-P., C. Chateau, M. Laurain, and M. Nauche. 1959. Paléontologie de Madagascar. XXVII: Les Poissons de la Sakmena moyenne. Ann. Paléont. 45:175–219.

Lison, L. 1941. Recherches sur la structure et l'histogénèse des dents des Poissons dipneustes. Arch. Biol. 52:279–320, 10 Abb., 1 Taf, Paris.

Ørvig, Tor. 1951. Histologic studies of Placoderms and fossil Elasmobranches. I: The endoskeleton, with remarks on the hard tissues of lower vertebrates in general. Ark. Zool. Ser. 2, 2:321–454, 22 Abb., 8 Taf, Paris.

Ørvig, Tor. 1967. Phylogeny of tooth tissues: evolution of some calcified tissues in early vertebrates. In: Structural and chemical organization of teeth (E. A. W. Miles and R. C. Greulich eds.), 1:45–110, 53 Abb., Academic Press, New York, London.

Ostrom, J. H. 1970. Stratigraphy and paleontology of the Cloverly Formation (Lower Cretaceous) of the Bighorn Basin Area, Wyoming and Montana. Peabody Mus., Yale Univ., Bull. 35:VIII + 234 pp., 9 figs., 27 pl., 7 charts.

Peyer, B. 1918. Das Gebiß von *Ceratodus parvus* AG. nebst Beiträgen zur Kenntnis triassischer Ceratodontiden. Z. deutsch. Geol. Ges. 69(1917):18–73, Berlin.

Scott, R. W. 1970. Paleoecology and paleontology of the Lower Cretaceous Kiowa Formation, Kansas. Univ. Kansas Paleont. Contrib., Art. 52 (Cretaceous), 94 pp.

Smith, Moya M. 1979. Structure and histogenesis of tooth plates in *Sagenodus inaequalis* Owen considered in relation to the phylogeny of post-Devonian dipnoans. Proc. Roy. Soc. London, B, 204:15–39, 13 figs.

Tabaste, N. 1963. Étude de restes de poissons du Crétacé Saharien. Mém. I.F.A.N., 68, Mélanges Ichthyol: pp. 436–499.

Taquet, P. 1970. Sur le gisement de Dinosauriens et de Crocodiliens de Gadoufaoua (République du Niger). C. R. Acad. Sci. Paris 271:38–40.

Thurmond, J. T. 1974. Lower vertebrate faunas of the Trinity Division in North-Central Texas. Geoscience a. Man 8:103–129.

Vaughn, P. P. 1956. A second specimen of the Cretaceous crocodile *Dakotasuchus* from Kansas. Trans. Kansas Acad. Sci., 59:379–381.

Vorobyeva, E. I. 1967. Triasovbii ceratod iz juznoi fergany i nekotorye zamecanija o sisteme i filogenii ceratodontid (Triassic Ceratod from South Ferghana and Remarks on the Systematics and Phylogeny of Ceratodontids). Paleont. Zh. 1967, Nr. 4:102–111.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
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# *Coluber mormon*, a Species Distinct from *C. constrictor*

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## ABSTRACT

For more than 100 years *Coluber constrictor mormon* has been recognized as a subspecies of the eastern racer. However, trenchant differences exist between *mormon* and the neighboring *C. c. flaviventris* in numbers of maxillary and dentary teeth, and there are even greater differences in ecological traits including relative size of egg and number of eggs per clutch. Also, there are average differences in body size, proportions, color, numbers of juvenile blotches, and numbers of supralabials, subcaudals and ventrals, but individual variation results in some overlap in each of these characters. The geographic ranges are widely separated by the physical barrier of the Rocky Mountains, and there is no intergradation. The Western Yellow-bellied Racer should be restored to its original status of a full species, *Coluber mormon*.

## HISTORICAL REVIEW

*Coluber mormon* Baird and Girard (1852) was named as a distinct species, from "Valley of the Great Salt Lake, Utah," and was subsequently found to be widely distributed over the Pacific Coast and Great Basin states. The close relationship of *C. mormon* with the eastern racers (*C. constrictor*) was early recognized. From 1863 onward (Jan, 1863), the trinomial was generally applied to *C. mormon* with use of various synonyms in different combinations (generic names *Bascanion, Bascanium, Coryphodon* and *Zamenis*; subspecific name *vetustum*). Some authors applied the subspecific (or specific) name, *flaviventris* to both Eastern and Western Yellow-bellied Racers. Van Denburgh (1922) defended the subspecific validity of *Coluber*

*constrictor mormon* against those contemporaries who synonymized it under *C. c. flaviventris* (e.g., Ditmars, 1907; Stejneger and Barbour, 1917) and wrote: "The fact that more than half the specimens from west of the Rocky Mountains have eight labials while those from farther east usually have seven, causes us to continue to regard them as different subspecies." This judgment has remained the *status quo* for the past 59 years.

On the basis of accumulating evidence concerning distribution and ecology, Fitch (1963) wrote: ". . . the range of *mormon* seems to be entirely west of the Continental Divide, well separated from that of *flaviventris* by desert and mountain barriers. The conspecificity of *mormon* with the other subspecies needs to be more thoroughly investigated . . . ." Populations of *mormon* and *flaviventris* are sparse and scattered in the regions where they approach each other most closely and no series have been available for comparison of taxonomic characters. Our respective field studies of populations of *C. c. flaviventris* in northeastern Kansas (HSF) and *C. c. mormon* in northwestern Utah (WSB, WSP) reveal hitherto unrecognized additional differences that have definite bearing on their systematic relationships.

## Distinctive Characters

The drab and nondescript appearance of the racers has doubtless tended to mask the fact that there are important differences between *mormon* and *flaviventris*, some of which are subtle. Table 1 shows differences of many kinds and degrees. Individual variation bridges the gap between the two kinds in some characters, including all those of lepidosis. In other characters, however, the two are discrete entities.

The farming of a decisive statement setting forth the differences between *mormon* and *flaviventris* is complicated by the fact that both have extensive ranges and vary geographically, but this variation has not been analyzed. Superimposed on geographic variation are sexual and ontogenetic differences in many characters. Smith (1961) studied the geographic variation in three characters of *C. constrictor* in Illinois. He found evidence of north-to-south clines as shown by the following means: 176.7, 176.5, 179.1, 176.2, 178.7 (number of ventrals); 79.6, 83.6, 85.6, 87.7, 90.9 (number of caudals); and 21.7, 23.8, 23.5, 24.1, 24.4 (relative tail length). Series of males and females were combined to obtain the figures in Smith's samples, but the sexes also have average differences in each of these characters. In several characters such as size and color, *mormon* is more like *flaviventris* than like *Coluber c. constrictor* and other eastern subspecies. However, *mormon* cannot be considered the end form of an east-west cline. Both *mormon* and *flaviventris* seem to be remarkably homogeneous throughout their ranges in some of their distinctive characters. The clutch size of 5 or 6 eggs reported by Brown and Parker (1981) for Tooele County, Utah, is the same as that found for a West Coast sample (Museum of Vertebrate Zoology

Table 1. Diagnostic characters of *Coluber mormon* and *C. constrictor flaviventris*.

| Characters | *C. mormon* Mean, or typical number or condition | N | Range | *C. c. flaviventris* Mean, or typical number or condition | N | Range | Source* |
|---|---|---|---|---|---|---|---|
| Number of teeth | | | | | | | |
| Dentary | | | 14–16 | | | 18–19 | Ort. |
| Maxillary | | | 13–14 | | | 15–16 | Ort. |
| Eggs | | | | | | | |
| Number per clutch | 6.44 ± 0.26 | 43 cl | 4–11 | 11.8 | 82 | 5–26 | B&P, F[2] |
| Egg wt. as % ♀ wt. | 11.4 | | | 3.68 | 150 eggs<br>50 ♀♀ | | B&P, F[2] |
| Dimensions (mm) | 37.8 ± 18.0 | 54 | | 29.4 × 19.6 | 150 | | B&P, F[2] |
| Size | | | | | | | |
| ♂ S–V (mm) | 537 ± 6.10 | 131 | 395–695 | 721 ± 8.34 | 181 | 513–1110 | B&P, F[1] |
| ♀ S–V (mm) | 578 ± 6.70 | 114 | 405–735 | 795 ± 11.16 | 177 | 538–1210 | B&P, F[1] |
| ♂ Weight (g) | 55.6 ± 1.67 | 136 | 23.5–97.2 | 123.14 ± 7.56 | 50 | 55–224 | B&P, F[1] |
| ♀ Weight (g) | 68.6 ± 2.15 | 114 | 24.4–128.6 | 155.33 ± 11.44 | 50 | 53–350 | B&P, F[1] |
| Proportions | | | | | | | |
| Ratio tail/total lgth. ♂ | 26.76 ± .11 | 73 | 23.9–28.9 | 23.2 | 360 | | B&P, F[2] |
| Ratio tail/total lgth. ♀ | 25.07 ± .09 | 72 | 23.1–27.0 | 20.9 | 376 | | B&P, F[2] |
| Habitus | stockier (see Fig. 1) | | | more slender (see Fig. 1) | | | B&P, F[1] |
| Color and pattern | | | | | | | |
| Juv. dorsal blotches | | | 70–85 | | | 65–80 | Ort. |
| Adult dorsal color | pale olive gray | | | dark slaty gray | | | Ort. |
| Lepidosis | | | | | | | |
| Supralabial pairs | 8 | | | 7 | | | Ort. |
| Subcaudal pairs | 88.7 | | | 84.0 | | | Ort. |
| Ventrals | 171.1 | | 160–184 | 174.3 | | 163–194 | Ort. |

*B & P—Brown and Parker ms, F[1]—Fitch mss, F[2]—Fitch 1963, Ort.—Ortenberger 1928.

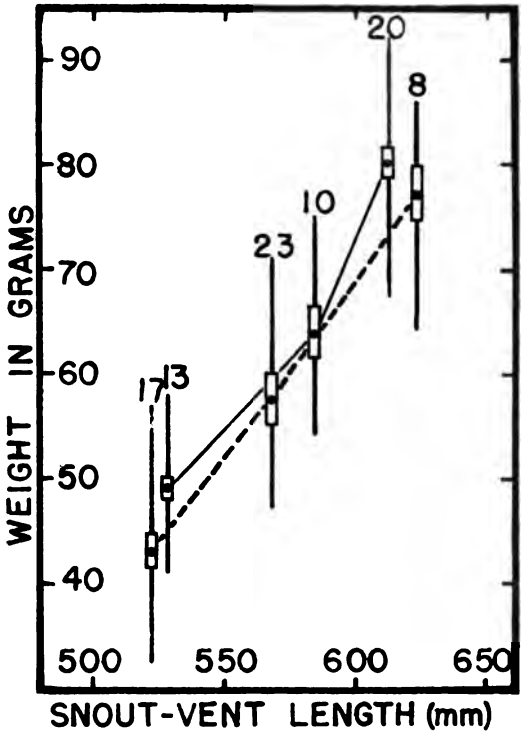


Fig. 1. Length vs. weight plotted for similar sized series of *C. mormon* (upper series of each pair, connected by solid line) and *C. c. flaviventris* (lower series, connected by broken line) showing that *C. mormon* averages heavier for each length. Mean, standard error, range and number of specimens are shown for each sample.

specimens, n = 43; Fitch, 1970) and is only about half the mean clutch of *flaviventris*.

## Range Relationships

Differences such as those indicated in Table 1 do not in themselves demonstrate the specific distinctness of the two western racers. Geographic intergradation is the standard criterion of subspecific status in adjacent differentiated populations. Conversely, the existence of allopatric ranges that come in contact without intergradation (either with no interbreeding, or with production of occasional anomalous hybrids) is acceptable evidence of full species status. Where a barrier separates the ranges so that no contact between individuals of the two kinds is possible in nature, subjective judgments become involved and *potential* interbreeding may be cited as a basis for conspecificity. But, depending on the degree of differentiation, specific status is usually indicated.

The range relationships of *mormon* and *flaviventris* have long been poorly understood. Their ranges have often been mapped as widely contiguous (Behler and King, 1979; Shaw and Campbell, 1974; Stebbins, 1954, 1966; Wright and Wright, 1957) and there are statements in the literature to the effect that geographic intergradation occurs. However, Wilson's (1978) more detailed map of actual localities suggests that there is a broad and continuous hiatus of uninhabitable terrain which separates the range of *flaviventris* on the east from that of *mormon* on the west. This general pattern is broken by just one anomalous specimen (Stuart, 1930) as explained below. In the past it seems to have been generally assumed that gaps between the known ranges could be attributed to lack of collecting, and that these gaps would be filled by further fieldwork. In several recent decades, however, no progress in bridging the hiatus has been made. Racers are not rare or secretive and no extensive areas of the continental United States remain unexplored herpetologically. The accumulated locality records certainly should reflect the actual ranges fairly well.

The distribution of *Coluber* in Wyoming has recently been clarified by Baxter and Stone (1980), who showed that *mormon* does not reach the western edge of the state, although it occurs in nearby eastern Idaho and northern Utah. The many Wyoming records of *flaviventris* are all substantially to the east of the Continental Divide, mostly in the eastern half of the state. The westernmost occurrences are in the vicinity of Lander, Fremont County, near the east base of the Wind River Mountains. In an early account of the fauna and life zones of Wyoming, Cary (1917) listed *Bascanion* [=*Coluber*] *constrictor* as characteristic of the upper Sonoran Life Zone, i.e., of the lower and warmer areas of the state. In general, the many locality records shown by Baxter and Stone (1980) bear out this correlation, but a few are within the Transition Zone. The Wind River Range and Red Desert constitute obvious physical barriers barring *flaviventris* from the western parts of Wyoming and from contacts with *mormon* in adjacent eastern Idaho and northeastern Utah.

Maslin (1959) and Smith et al. (1965) listed Colorado localities and indicated the range of *flaviventris* within the state to be the Great Plains extending to the base of the Rocky Mountains. Racers were shown to be absent from the mountainous western half of the state, except for records of *mormon* along the Colorado River near the Utah border in Mesa County (Grand Junction; 3 miles east of Fruita and 2 miles west of Grand Junction) and Garfield County (Roan Creek Road). South of the Colorado-Utah border both *flaviventris* and *mormon* seem to be present only in relict and widely separated populations, *mormon* at Lake Meade, Nevada, and Eagar, Apache County, east-central Arizona; *flaviventris* in the upper Rio Grande Valley of New Mexico.

Racers (*Coluber constrictor oaxaca*) have been found in small numbers

and at widely scattered localities over much of Mexico (Chiapas, Coahuila, Colima, Durango, Oaxaca) and southeast into Guatemala. Smith (1971) examined all available Mexican material, checking the specimens especially for *mormon* characters, but found that all were assignable to *oaxaca* (formerly *C. c. stejnegerianus*, best known from the lower Rio Grande Valley). Intergradation between *oaxaca* and *flaviventris* occurs in southern Texas where their ranges meet, but *oaxaca* does not intergrade with *mormon*. Their known ranges are separated by hundreds of miles of generally uninhabitable terrain.

The few records in Montana are mostly of *flaviventris* and are mainly in the eastern and southern parts. Three records are of particular interest. Mossiman and Rabb (1952) recorded one specimen of *flaviventris* in the Tiber Reservoir region near the Canadian border to the north and near the east base of the Rocky Mountains to the west, remote from other known occurrences. On the western edge of the state, Rodgers and Jellison (1942) recorded *mormon* near Hamilton (Skalkaho Canyon, Ravalli County) in the Columbia River drainage, and not far from other known occurrences in adjacent northern Idaho. Lastly, Stuart (1930) noted a specimen which he identified as *mormon*, from 8 miles east of Big Timber, Sweet County, Montana, far to the east of the Continental Divide in the valley of the Yellowstone River. The identification as *mormon*, in an area where *flaviventris* might be expected, was made on the basis of supralabials (8), maxillary teeth (13) and dentary teeth (16). The specimen was an adult female, and contained seven large eggs, suggesting affinity to *mormon* rather than *flaviventris*. This single and anomalous specimen seems to confuse rather than clarify the relationship between the two forms. It may be an abnormal "*mormon*-like" example of *flaviventris*. Or it may represent a small and well isolated relict population of *mormon* surviving from a past time of warmer climate when that species was able to cross the Continental Divide and establish itself east of the Rocky Mountains.

The distribution of racers in Canada has been reviewed by Froom (1972) and Cook and De Jong (1975). Cook stated that *mormon* occurs in the dry interior of British Columbia in the Okanagan, Similkameem and Fraser Valleys, from Seton Lake and Kamloops east to Midway. For *flaviventris* the only records are from Saskatchewan, Val Marie, a few kilometers north of the Montana border and approximately 880 km east across the Rocky Mountains from the nearest *mormon* locality in Canada, and near Big Muddy Lake, approximately 234 km farther east.

It appears that racers are almost entirely absent from the Rocky Mountain region. The mountains constitute a barrier much broader than shown on published range maps, across the western parts of Montana, Wyoming, Colorado and New Mexico, separating the range of *mormon* on the west from that of *flaviventris* on the east. There are important morphological,

physiological and ecological differences between the two taxa and intergradation does not occur. In summary, we believe that the evidence here presented provides a strong case for the recognition of *Coluber mormon* as a full species. However, we suggest the need for a thoroughgoing study of geographic variation in many external and internal characters (e.g., enzyme polymorphism, karyotypes, osteology, scutellation). We believe that a systematic revision at the species level will support our conclusion regarding the specific distinctions of *C. mormon*.

Many more or less parallel cases could be cited of closely related eastern and western species partly or completely separated by a barrier in the Rocky Mountain region. Among reptiles the eastern *Lampropeltis triangulum*, *Sceloporus undulatus* and *Crotaphytus collaris* with their western counterparts *L. pyromelana-multicincta*, *S. occidentalis* and *C. insularis* come to mind.

## Literature Cited

Baird, S. F., and C. Girard. 1852. Reptiles. Appendix C, pp. 336–353 *in* Stansbury, H. Exploration and survey of the valley of the Great Salt Lake, Utah, including reconnaissance of a new route through to the Rocky Mountains. Lippincott, Crambo and Company.

Baxter, G. T., and M. D. Stone. 1980. Amphibians and reptiles of Wyoming. Wyoming Game and Fish Dept. Bull. 11:vi + 135 pp. Cheyenne.

Behler, J. L., and F. W. King. 1979. The Audubon Society field guide to North American reptiles and amphibians. Alfred Knopf, New York. 720 pp.

Brown, W. S., and W. S. Parker. 1981. Growth, reproduction and demography of the racer, *Coluber constrictor mormon*, in northern Utah. *In* R. A. Seigel, ed., Contributions to Vertebrate Ecology and Systematics: A Tribute to Henry S. Fitch. Spec. Publ. Univ. Kansas Mus. Nat. Hist., in press.

Cary, M. 1917. Life-zone investigations in Wyoming. North American Fauna, 42:1–95. U.S. Dept. Agr., Bureau Biol. Survey.

Cook, F. R., and C. G. V. Z. De Jong. 1975. Eastern yellow-bellied racer in central southern Saskatchewan. Canadian Field-Naturalist, 89:174–175.

Cope, E. D. 1875. North American Batrachia and Reptilia. Bull. U.S. Nat. Mus. 1:21–23, 33–44.

Ditmars, R. L. 1907. The Reptile book. Doubleday, Page and Company, N.Y.

Fitch, H. S. 1963. Natural history of the racer *Coluber constrictor*. Univ. Kansas Publ. Mus. Nat. Hist. 15(8):351–468.

Fitch, H. S. 1970. Reproductive cycles of lizards and snakes. Univ. Kansas Mus. Nat. Hist. Misc. Publ. 52:1–247.

Froom, B. 1972. The snakes of Canada. McClelland and Stewart, Ltd., Toronto.

Jan, G. 1863. Elenco sistematica degli ofidi. Arch. Anat. e Fisiol. Zool. (Canestrini) 2:1–76.

Maslin, T. P. 1959. An annotated check list of the amphibians and reptiles of Colorado. Univ. Colorado Studies. Ser. Biol. 6:1–98.

Mossiman, J. E., and G. B. Rabb. 1952. The herpetology of the Tiber Reservoir area, Montana. Copeia 1952(1):23–27.

Ortenburger, A. I. 1928. The whip snakes and racers, genera *Masticophis* and *Coluber*. Mem. Univ. Michigan Mus. 1:xviii + 247 pp.

Rodgers, T. L., and W. L. Jellison. 1942. A collection of amphibians and reptiles from western Montana. Copeia 1942:10–13.

Shaw, C. E., and S. Campbell. 1974. Snakes of the American West. Alfred Knopf, Inc., New York. xii + 292 pp.

Smith, H. M. 1971. Distribution of the racer, *Coluber constrictor*, in Mexico. Jour. Herpetology 5(3–4):212–214.

Smith, H. M., T. P. Maslin, and R. L. Brown. 1965. Summary of the distribution of the herpetofauna of Colorado. Univ. Colorado Studies, Ser. Biol. 15, 52 pp.

Smith, P. W. 1961. The amphibians and reptiles of Illinois. Bull. Illinois Nat. Hist. Survey 28(1):1–298.

Stebbins, R. C. 1954. Amphibians and reptiles of western North America. McGraw Hill, Inc., New York. xii + 528 pp.

Stebbins, R. C. 1966. A field guide to western reptiles and amphibians. Houghton Mifflin Co., Boston. 279 pp.

Stejneger, L., and T. Barbour. 1917. A check list of North American amphibians and reptiles. Harvard Univ. Press, Cambridge. 125 pp.

Stuart, L. C. 1930. An extension of the range of *Coluber constrictor mormon* (Baird and Girard). Copeia 1930:44.

Van Denburgh, J. 1922. The reptiles of western North America. Occas. Papers California Acad. Sci. 10:1–1028.

Wilson, L. D. 1978. Coluber constrictor. Catalogue of American amphibians and reptiles. Society for Study of American Amphibians and Reptiles 218:1–4.

Wright, A. H., and A. A. Wright. 1957. Handbook of snakes of the United States and Canada. Comstock Publ. Associates, Cornell Univ. Press, vol. 1, xviii + 564 pp.

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# New County Records of Amphibians and Reptiles in Kansas

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ABSTRACT

Twenty-three specimens of reptiles and amphibians are reported which are new county records. All specimens are housed in the Museum of the High Plains, Fort Hays State University, Hays, Kansas.

No comprehensive work on the herpetofauna of Kansas existed prior to Smith's (1950) "Handbook of Amphibians and Reptiles of Kansas," which was revised in 1956. Collins (1974) published an updated "Amphibians and Reptiles in Kansas." Collins' volume and subsequent publications by the Kansas Biological Survey have provided more precise information on the natural history and distribution of amphibians and reptiles in Kansas.

Herein is added new distributional data, by county, of twenty-three amphibians and reptiles in Kansas with capture data as available. All specimens are housed in the Museum of the High Plains (MHP), Fort Hays State University, Hays, Kansas. All common and scientific names are taken from Collins et al. (1978).

### American Toad (*Bufo americanus*)

MHP 5754. Neosho Co: T.30S, R.20E, sec. 22 [=Neosho County State Lake, 11 mi. (17.5 km) S, 2 mi. (3.2 km) E Erie]. 28 April 1978. N. J. Hilscher, collector.

The existence of this species in Neosho County was expected, but previously unrecorded. It has been reported from all of the surrounding counties except Bourbon County to the northeast (Collins, 1974).

### Blanchard's Cricket Frog (*Acris crepitans blanchardi*)

MHP 5687. Morton Co: 9 mi. (14.5 km) N, 3 mi. (4.8 km) E Elkhart (T.33S, R.41W, NE ¼ sec. 35). 8 April 1978. R. B. Wilhelm, collector.

This specimen extends the known range of this species in Kansas approximately 45 miles (72 km) to the west from the nearest record in Seward County (Collins, pers. comm.).

Plains Leopard Frog (*Rana blairi*)

MHP 6258. Saline Co: 4½ mi. (7.2 km) S, 5½ mi. (8.8 km) E Salina (T.15S, R.2W, N ½ sec. 25). 4 May 1980. S. D. Lang, collector.

The specimen was captured by hand on the bank of a small creek below a pasture pond at 1:00 p.m. with the air temperature in the seventies and the sky clear. The existence of this species in Saline County was expected, but remained unrecorded.

Common Snapping Turtle (*Chelydra serpentina serpentina*)

MHP 5843. Rush Co: T.16S, R.18W, SE ¼ sec. 21 [=1 mi. (1.6 km) S Liebenthal]. 9 May 1978. T. Hardy, collector.

This specimen was taken approximately 12 miles (19.2 km) south of the nearest record in Ellis County. It extends the somewhat spotty distribution of this species in western Kansas (Collins, 1974).

Ornate Box Turtle (*Terrapene ornata ornata*)

MHP 6050. Norton Co: 3 mi. (4.8 km) S, 1 mi. (1.6 km) E Almena [=T.2S, R.21W, SE ¼ sec. 28]. 25 June 1976. N. L. Malcolm, collector.

MHP 5820. Rush Co: 1 mi. (1.6 km) N, 6 mi. (9.6 km) W Rush Center (Walnut Creek) [=T.18S, R.19W, NW ¼ sec. 22]. 8 April 1978. R. Wagner, collector.

MHP 6194. Sherman Co: 11 mi. (17.6 km) S, 3½ mi. (5.6 km) W Goodland (T.10S, R.40W, N ½ sec. 15). 15 September 1979. M. S. Rush, collector. This specimen was taken in short-grass prairie in a moist depression near Sherman County State Lake.

None of the above three specimens represents an extension in the range of this species in Kansas, but all help to fill in the known geographical range within the state (Collins, 1974).

Red-eared Slider (*Chrysemys scripta elegans*)

MHP 6253. Neosho Co: Lake Parsons (T.30S, R.19E, sec. 16). 26 April 1980. S. J. Valek, collector. Shell only.

Midland Smooth Softshell (*Trionyx muticus muticus*)

MHP 2745. Ellis Co: ½ mi. (0.8 km) N Pfeifer, Smoky Hill River [=T.15S, R.17W, SW ¼ sec. 25]. 4 May 1964. J. Flake, collector.

No capture data are available with this specimen. It is, however, the westernmost record for this species from a western tributary of the Kansas River except for a specimen reported by Smith (1950) that he never examined and that Collins (1974) did not cite.

An additional record of this species (MHP 6221) was taken in Ellis County from 15¼ mi. (24.4 km) N and 1 mi. (1.6 km) E of Hays on the Saline River (T.11S, R.18W, E ½ sec. 15) on 27 February 1980 by M. Eberle.

These records indicate breeding populations approximately 100 miles west from the nearest record in this river system.

Southern Coal Skink (*Eumeces anthracinus pluvialis*)

MHP 6255. Neosho Co: 10 mi. (16 km) S, 2½ mi. (4 km) E Erie, Neosho Co. St. Lake #2 (T.30S, R.20E, NE ¼ sec. 22). 26 April 1980. S. G. Jorgenson, collector.

This specimen was taken 30 miles NW of the nearest record in Cherokee County (Collins, pers. comm.). It was collected under a piece of scrap metal on a hillside covered with trash, rocks, and leaf litter. The air temperature was 55°F (13°C).

Prairie Ringneck Snake (*Diadophis punctatus arnyi*)

MHP 6252. Coffey Co: John Redmond Reservoir (T. 20S, R.13E, sec. 32). 27 April 1980. B. Rhodes, collector.

MHP 6257. Saline Co: 1 mi. (1.6 km) E Salina (T.14S, R.2W, SW ¼ sec. 21). 4 May 1980. S. D. Lang, collector.

These specimens represent no significant range extension in Kansas, but previously were not recorded in these counties (Collins, 1974).

Eastern Hognose Snake (*Heterodon platyrhinos*)

MHP 6271. Russell Co: 5 mi. N, 2 mi. W Russell (T.12S, R.14W, NW ¼ sec. 4). 11 August 1980. T. A. Nulton, collector. This specimen serves to fill in the somewhat spotty known distribution of this species in Kansas (Collins, 1974).

Rough Green Snake (*Opheodrys aestivus*)

MHP 6256. Neosho Co: 10 mi. (16 km) S, 2½ mi. (4 km) E Erie, Neosho Co. St. Lake #2 (T.30S, R.20E, NE ¼ sec. 22). 26 April 1980. R. S. Mellott, collector. This specimen was taken under a log from a woody hillside. The air temperature was 55°F (13°C).

This is within the known range of this species in Kansas, but was previously unrecorded in this county (Collins, 1974).

Eastern Yellowbelly Racer (*Coluber constrictor flaviventris*)

MHP 5660. Osborne Co: T.9S, R.12W, NE ¼ sec. 30 [=13 mi. (20.8 km) S Osborne]. 22 August 1966. D. R. Ittner, collector.

This species occurs throughout Kansas, but previously was unrecorded in this county (Collins, 1974).

Eastern Coachwhip (*Masticophis flagellum flagellum*)

MHP 6114. Bourbon Co: T.26S, R.21E, NE ¼ sec. 14 [=Bourbon Co. St. Lake, 4 mi. (6.4 km) S, 5 mi. (8 km) W Uniontown]. 10 May 1969. U. G. Hutton, collector.

This is the northeastern most record of this species in Kansas and represents a significant range extension. It was taken 60 miles NNW of Cherokee County record and 45 miles NE of the Wilson County record (Collins, pers. comm.).

Great Plains Rat Snake (*Elaphe guttata emoryi*)

MHP 6261. Crawford Co: 8¾ mi. (14 km) N, 2 mi. (3.2 km) E Girard. (T.28S, R.24E, NE ¼ sec. 5). 26 April 1980. M. S. Rush, collector.

This specimen was taken between two large flat rocks at the top of a rocky, woody hillside on the edge of a pasture. The air temperature was 55°F (13°C) on an overcast day. This specimen extends the range of this species in southeastern Kansas 45 miles east of the nearest record in Wilson County (Collins, pers. comm.).

MHP 5863. Kiowa Co: 10 mi. (16 km) S, 2 mi. (3.2 km) E Greensburg (T.30S, R.18W, SE ¼ sec. 2). 15 April 1978. J. C. Burns, collector.

This is within the known range of this species in Kansas, but was previously unrecorded in Kiowa County (Collins, 1974).

Kansas Glossy Snake (*Arizona elegans elegans*)

MHP 5870. Kiowa Co: 6 mi. (9.6 km) W, ¾ mi. (1.2 km) E Haviland (T.29S, R.16W, NE ¼ sec. 17). 3 October 1976. J. C. Burns, collector. This specimen was taken within the known range of this species in southern Kansas, but was previously unrecorded in Kiowa County (Collins, 1974).

Western Ribbon Snake (*Thamnophis proximus proximus*)

MHP 6254. Trego Co: 16½ mi. (26.4 km) S, 9¼ mi. (14.8 km) E Wa-Keeney (T.15S, R.22W, NE ¼ sec. 1). 20 March 1980. R. E. Cooper, collector.

This specimen was taken from the grassy banks of an intermittent stream. The air temperature was approximately 50°F (10°C).

This locale is on the western edge of the known geographical range for this subspecies (Collins, 1974).

Lined Snake (*Tropidoclonion lineatum*)

MHP 6251. Crawford Co: 8¾ mi. (14 km) N, 2 mi. (3.2 km) E Girard (T.28S, R.24E, NE ¼ sec. 5). 26 April 1980. S. M. Royal, collector.

This specimen was taken beneath a rock on a rocky hillside. The air temperature was 55°F (13°C) on an overcast day.

This is the southeastern most record of this species in Kansas, but is within the range of the species. It was collected 25 miles (40 km) southeast of the nearest record in Bourbon County (Collins, pers. comm.).

### Northern Water Snake (*Nerodia sipedon sipedon*)

MHP 6259. Saline Co: 4½ mi. (7.2 km) S, 5½ mi. (8.8 km) E Salina (T.15S, R.2W, N ½ sec. 25). 4 May 1980. S. D. Lang, collector.

This specimen was collected from a pasture pond spillway at an air temperature of approximately 75°F (24°C).

This locale is within the range of this species in Kansas but previously was unrecorded from this county (Collins, 1974).

### Western Massasauga (*Sistrurus catenatus tergeminus*)

MHP 6260. Rush Co: 3 mi. (4.8 km) E Liebenthal (T.16S, R.18W, SW ¼ sec. 13). 10 May 1980. K. Thompson, collector.

This locale is on the western edge of the range of this subspecies in Kansas. The Ellis County specimen (Collins, 1974) cannot be found, but the above locality is 35 miles (56 km) WNW of the nearest Barton County record (Collins, pers. comm.).

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## Literature Cited

Caldwell, J., and J. T. Collins. 1977. New records of fishes, amphibians and reptiles in Kansas, pp. 63–78. *In* J. Caldwell (ed.) New records of the fauna and flora of Kansas for 1976. Tech. Publ. St. Biol. Surv. Kansas, No. 4.

Collins, J. T. 1974. Amphibians and reptiles in Kansas. Univ. Kansas Mus. Nat. Hist. Pub. Ed. Ser. 1:1–283.

Collins, J. T. 1979. New records of fishes, amphibians and reptiles in Kansas, pp. 56–66. *In* R. E. Brooks (ed.) New records of the fauna and flora of Kansas for 1978. Tech. Publ. St. Biol. Surv. Kansas, No. 8.

Collins, J. T. 1980. New records of fishes, amphibians and reptiles in Kansas for 1979, pp. 1–11. *In* R. E. Brooks (ed.) New records of the fauna and flora of Kansas for 1979. Tech. Publ. St. Biol. Surv. Kansas, No. 9.

Collins, J. T., and J. Caldwell. 1976. New records of fishes, amphibians, and reptiles in Kansas, pp. 78–97. *In* J. Caldwell (ed.) New records of the fauna and flora of Kansas for 1975. Tech. Publ. St. Biol. Surv. Kansas, No. 1.

Collins, J. T., and J. Caldwell. 1978. New records of fishes, amphibians and reptiles in Kansas for 1977, pp. 70–88. *In* R. E. Brooks and R. L. McGregor (eds.) New records of the fauna and flora of Kansas for 1977. Tech. Publ. St. Biol. Surv. Kansas, No. 6.

Collins, J. T., J. E. Huheey, J. L. Knight, and H. M. Smith. 1978. Standard common and current scientific names for North American amphibians and reptiles. Soc. Study Amp. and Rep., Misc. Publ. Herpet. Circ. 7:iv+36.

Smith, H. M. 1950. Handbook of amphibians and reptiles of Kansas. Univ. Kansas Mus. Nat. Hist. Misc. Publ. No. 2:1–336.

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# Efficacy of Nematicides in Corn in Western Kansas

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## ABSTRACT

Nematodes (*Pratylenchus* spp.) of corn were reduced an average of 45.2% by seven chemical treatments during two seasons at nine western Kansas sites. Carbofuran at 0.84, 1.12, 1.68 and 2.25 kg (a.i.)/ha reduced nematodes 84.5, 53.3, 67.6 and 47.1% respectively; ethoprop at 2.25 and 4.5 kg (a.i.)/ha reduced nematodes 21.2 and 59.4%; and terbufos at 1.12 and 1.68 kg (a.i.)/ha reduced nematodes 23.0 and 58.9%. Other plant-parasitic nematodes found were *Helicotylenchus* sp., *Hoplolaimus* sp., *Tylenchorhynchus* sp. and *Xiphinema* sp. No significant differences in yield due to nematode control were obtained at any site tested.

Corn, a major crop in Kansas, is reduced by disease about 10% annually (Sim, 1979). More than 40 species of nematodes have been reported feeding on or living in association with corn (Johnson and Dickson, 1973; Norton and Hinz, 1976; Norton, 1978; Shurtleff, 1973; Rhoades, 1978). Several plant-parasitic nematodes are associated with corn in Kansas (O. J. Dickerson, L. D. Lash, unpublished), but reported research showing their economic potential is scarce. The results reported here add to information concerning efficacy of chemical control of nematodes (Bergeson, 1978; Smolik, 1975; Rhoades, 1968; Rhoades, 1978) and the economic potential of nematodes in corn.

## MATERIALS AND METHODS

*1978*. Three fields were chosen in western Kansas which had shown declining corn yields in the past. The exact nature of these declines was not known, but samples had shown relatively high numbers of *Pratylenchus* spp. nematodes and it was thought that nematodes might be involved. These fields were located in Cheyenne County (CN), Scott County (SC) and Stevens County (SV). Tests at SC and SV consisted of large field plots treated with carbofuran at 0, 1.12 and 2.25 kg (a.i.)/ha in cooperation with Food Machinery Corporation. Terbufos at 1.12 kg (a.i.)/ha was included at SC. Plots at SC were 0.5 ha in size in a completely randomized design with three replications, and plots at SV were 0.2 ha in size in a completely randomized

design with six replications. Corn ('Funks 4507' and 'Pioneer 3388') was planted respectively at SC Apr 27 and at SV May 20. At CN aldicarb at 1.68 kg (a.i.)/ha, carbofuran at 0.84 and 1.68 kg (a.i.)/ha, Nem-A-Tak at 1.68 kg (a.i.)/ha, oxamyl at 1.12 and 1.68 kg (a.i.)/ha and terbufos at 1.68 kg (a.i.)/ha was applied to plots consisting of four 12-m rows spaced 76 cm apart. Plots were in a randomized complete block design with three replications. Corn ('McCurdy MSX 84') was planted May 19.

At all locations treatments were 17.8 cm bands incorporated into the top 7.6 cm of the row immediately after planting. Soil and root samples were taken at monthly intervals from preplanting through harvest. Four samples were taken every 80-m per plot at SC and SV, and 16 samples were taken per plot at CN. Each sample consisted of one quarter root and crown system. Grain yields were measured by harvesting all rows in each plot at SC and SV and the inner two rows at CN.

*1979.* During the growing season of 1978 a number of fields were observed having symptoms indicative of nematode damage—stunting, wilting, root pruning and high nematode counts when assayed. Areas showing these types of symptoms were marked and test plots placed in these areas in 1979. Plots were established in six western Kansas locations: Cheyenne (CN), Finney (FI), Grant (GT), Gray (GY), Scott (SC) and Stevens (SV) counties. History of the six sites follows:

1. CN—Corn variety = McCurdy MSX 84. Planted May 7; Keith Ulysses silt loam (pH 6.7, O.M. 2.1%); continuous corn for 15 years; furrow irrigated.
2. FI—Corn variety = O's Gold 5500. Planted May 14; Richfield silt loam (pH 7.8, O.M. 1.7%); continuous corn for three years; furrow irrigated.
3. GT—Corn variety = Pioneer 3183. Planted May 10; Ulysses Richfield sandy clay loam (pH 8.0, O.M. 1.0%); continuous corn for four years; furrow irrigated.
4. GY—Corn variety = NC+ 4666. Planted May 8: Pratt-Tivoli loamy fine sand (pH 7.6, O.M. 0.6%); continuous corn for three years; sprinkle irrigated.
5. SC—Corn variety = Funks 4507. Planted May 11; Richfield silt loam (pH 7.0, O.M. 2.1%); continuous corn for ten years; furrow irrigated.
6. SV—Corn variety = Pioneer 3388. Planted May 16; Ulysses silt loam (pH 7.5, O.M. 1.5%); continuous corn for four years; furrow irrigated.

Granular nematicide treatments at CN consisted of aldicarb, carbofuran, ethoprop, fonofos and oxamyl (Table 2). Treatments at GT, GY, SC and SV consisted of carbofuran, ethoprop, fonofos and terbufos (Tables 1 and 2). Treatments at FI consisted of carbofuran and ethoprop (Table 2). Untreated plots were controls.

In all locations in 1979 nematicides were applied immediately after plant-

Table 1. The effect of chemical treatments on grain yield and *Pratylenchus* spp. nematode populations in corn in six locations in western Kansas, 1978–1979.

| 1978 | | | | 1979 | | | |
|---|---|---|---|---|---|---|---|
| Treatment | Rate kg (a.i.)/ha | Nemas[a] /g dry root wt | Yield kg/ha | Treatment | Rate kg (a.i.)/ha | Nemas[b] /g dry root wt | Yield kg/ha |
| SCOTT COUNTY | | | | GRAY COUNTY | | | |
| No treatment | | 1356 | 12,162 | No treatment | | 6966 | 7593 |
| Carbofuran (10G) | 1.12 | 316 | 12,057 | Carbofuran (10G) | 1.12 | 2646 | 7593 |
| Carbofuran (10G) | 2.25 | 430 | 12,115 | Carbofuran (10G) | 2.25 | 2922 | 8723 |
| Terbufos (15G) | 1.12 | 737 | 11,899 | Ethoprop (10G) | 2.25 | 4420 | 7405 |
| | | | | Fonofos (10G) | 1.12 | 12,489 | 7091 |
| | | | | Terbufos (15G) | 1.12 | 2309 | 7091 |
| STEVENS COUNTY | | | | STEVENS COUNTY | | | |
| No treatment | | 5341 | 6788 | No treatment | | 2956 | 9978 |
| Carbofuran (10G) | 1.12 | 790* | 6455 | Carbofuran (10G) | 1.12 | 1306 | 11,735 |
| Carbofuran (10G) | 2.25 | 992* | 6974 | Carbofuran (10G) | 2.25 | 1169 | 8735 |
| | | | | Ethoprop (10G) | 2.25 | 2956 | 12,111 |
| | | | | Fonofos (20G) | 1.12 | 7849 | 10,542 |
| | | | | Terbufos (15G) | 1.12 | 6616 | 11,233 |
| CHEYENNE COUNTY | | | | FINNEY COUNTY | | | |
| No treatment | | 278 | 10,292 | No treatment | | 3272 | 7719 |
| Aldicarb (15G) | 1.68 | 19 | 10,416 | Carbofuran (10G) | 1.12 | 553* | 7217 |
| Carbofuran (10G) | 0.84 | 43 | 11,547 | Carbofuran (10G) | 2.25 | 670* | 7468 |
| Carbofuran (10G) | 1.68 | 90 | 10,606 | Ethoprop (10G) | 2.25 | 1295* | 6903 |
| Nem-A-Tak (15G) | 1.68 | 674 | 9978 | Ethoprop (10G) | 4.5 | 1569* | 7907 |
| Oxamyl (10G) | 1.12 | 52 | 9602 | Ethoprop (15G) | 2.25 | 766* | 7154 |
| Oxamyl (10G) | 1.68 | 155 | 9790 | Ethoprop (15G) | 4.5 | 777* | 6715 |
| Terbufos (15G) | 1.68 | 1114 | 10,292 | | | | |

[a] Nematode counts are from samples taken Aug 14 for Scott, Aug 2 for Stevens and Oct 6 for Cheyenne.
[b] Nematode counts are from samples taken July 27.
* Significantly different at the 5% level.

Table 2. Effects of nematicide treatments on *Pratylenchus* spp. numbers and corn yield at three western Kansas counties in 1979.

| Treatment | Rate kg (a.i.)/ha | Cheyenne Nema counts[a] /g dry root wt | Cheyenne Yield (kg/ha) | Grant[b] Nema counts[a] /g dry root wt | Scott[b] Nema counts[a] /g dry root wt |
|---|---|---|---|---|---|
| No treatment | | 3624 | 8593 | 2982 | 183 |
| Aldicarb (15G) | 1.12 | 1798 | 8655 | — | — |
| Aldicarb (15G) | 2.25 | 1720 | 7903 | — | — |
| Carbofuran (10G) | 1.12 | 692 | 8279 | 3866 | 212 |
| Carbofuran (10G) | 2.25 | 2911 | 8844 | 5537 | 40 |
| Ethoprop (10G) | 2.25 | 2706 | 8781 | 3820 | 7 |
| Ethoprop (10G) | 4.5 | 891 | 8844 | — | — |
| Ethoprop (15G) | 2.25 | 5784 | 8718 | — | — |
| Ethoprop (15G) | 4.5 | 4950 | 9157 | — | — |
| Fonofos (20G) | 1.12 | 2381 | 8844 | 3589 | 109 |
| Oxamyl (10G) | 1.12 | 77 | 8279 | — | — |
| Oxamyl (10G) | 4.5 | 326 | 9596 | — | — |
| Terbufos (15G) | 1.12 | — | — | 2861 | 85 |
| LSD 0.05 | | — | NS | NS | — |

[a] Nematode samples represent *Pratylenchus* spp. Samples from replicated plots in Cheyenne and Scott were lumped into one composite sample for each treatment; therefore, statistical analyses were not obtained. Samples were taken July 30 for Cheyenne and July 27 for Grant and Scott.

[b] Yields were not recorded in Grant and Scott.

ing in 17.8-cm bands with a one-row, hand-operated Gandy applicator and lightly incorporated into the top 7.6 cm with a rake or garden cultivator.

Because areas marked in 1978 for test sites were of different sizes, plot length varied from 6 m to 12 m. However, at all locations plots were four rows spaced 76 cm apart in a completely randomized design and replicated four times. Nematode samples consisted of eight one-quarter root systems from each of the two outside rows. Soil and root samples were taken at preplant and July 27 and 30.

Nematode samples from all locations both years were processed as follows: soil extractions were made by direct centrifugal flotation (Dickerson, 1971) of 100 cc of soil; root extractions were made on a continuous mist system with 10 g of roots.

Grain yields were measured in the plots in 1979 by harvesting the two middle rows of each plot.

## Results and Discussion

*1978.* Populations of *Pratylenchus* spp. were significantly reduced by treatments at SV but not at CN or SC (Table 1). Nematode populations in the soil were not found higher than 100/100 cc soil at any date throughout

the sampling period. Populations of *Pratylenchus* spp. exceeding 1000/g dry root wt. were found in the roots at SC and SV with population peaks in mid August to mid September. Nematode populations at CN were low and erratic. No significant differences in yield were obtained at CN, SC or SV (Table 1).

*1979. Pratylenchus* spp. were significantly reduced at FI but not at GY or SV (Table 1). At GY and SV (and at CN and SC in 1978) *Pratylenchus* spp. were reduced by each of several treatments, but the reductions were not significant, perhaps because of high variance within treatments. At FI, carbofuran at both rates and ethoprop (15G) at both rates seemed to control nematodes better than did ethoprop (10G). No significant differences in yield were obtained among treatments at FI, GY or SV (Table 1).

For some locations either yield or statistical analysis of nematode populations was not obtained; however, data are reported in Table 2.

Nematicide treatments were erratic in controlling nematode numbers, reducing them at several locations but not significantly. High variation in nematode numbers within treatments was a consistent problem and caused high LSDs. Lash and Dickerson (1979) reported similar experiences at other nematicide trials in western Kansas. Some samples seem to represent a "hot spot" or "low spot" with excessively high or low nematode populations. Lack of success in controlling nematode populations may reflect problems in sampling techniques, difficulty in chemical application or chemical ineffectiveness; but a problem in sampling techniques seems more likely. Increasing replication or sample numbers may help reduce the high variation within treatments and lead to lower LSD values. The average nematode reduction by chemical treatments in our tests over all locations both years was 45.21% (Table 3). Several chemicals consistently reduced nematode populations. Carbofuran reduced numbers 63.65%, ethoprop 31.26% and terbufos 40.9% (Table 3).

Soil samples yielded low and erratic populations of *Pratylenchus* spp. at all locations. Soil samples also contained other nematode populations. In the nine plot locations, plant-parasitic nematodes other than *Pratylenchus* spp. occurred in the following number of locations: *Helicotylenchus pseudorobustus* Golden—1; *Hoplolaimus galeatus* Cobb—1; *Tylenchorhynchus martini* Fielding—6; and *Xiphinema americanum* Cobb—3. In all cases, however, populations were too low to be considered economically important. *Pratylenchus* spp. identified from the various sites were *P. scribneri* Steiner, *P. alleni* Ferris, *P. neglectus* (Rensch) Filipjev and Schuurmans Stekhoven and occasionally *P. hexincisus* Taylor and Jenkins.

Yields in all locations in both years showed no significant response to any chemical treatment. The average yield response to chemical treatments in all plots was an increase of 9.24% (Table 3) representing an increase of 21.64 kg/ha (0.34 bu/a) based on the average of control yields (9018 kg/ha or 144

Table 3. Corn yield and nematode response to 18 chemical treatments in western Kansas in 1978–1979.

| Treatment | Rate kg (a.i.)/ha | No. locations tested | % Nema response[a] | No. locations harvested | % Yield response[a] |
|---|---|---|---|---|---|
| Aldicarb (15G) | 1.12 | 1 | 50.00 | 1 | 1.00 |
| Aldicarb (15G) | 1.68 | 1 | 93.26 | 1 | 1.18 |
| Aldicarb (15G) | 2.25 | 1 | 53.00 | 1 | −8.00 |
| Carbofuran (10G) | 0.84 | 1 | 84.50 | 1 | 10.87 |
| Carbofuran (10G) | 1.12 | 8 | 55.25 | 6 | 1.25 |
| Carbofuran (10G) | 1.68 | 1 | 67.60 | 1 | 2.75 |
| Carbofuran (10G) | 2.25 | 8 | 47.11 | 6 | 0.50 |
| Ethoprop (10G) | 2.25 | 6 | 21.20 | 4 | 1.65 |
| Ethoprop (10G) | 4.5 | 2 | 59.40 | 2 | 2.69 |
| Ethoprop (15G) | 2.25 | 2 | 19.80 | 2 | −0.66 |
| Ethoprop (15G) | 4.5 | 2 | 24.63 | 2 | −6.00 |
| Fonofos (20G) | 1.12 | 5 | −9.81 | 3 | 0.58 |
| Nem-A-Tak (15G) | 1.68 | 1 | −58.80 | 1 | −3.05 |
| Oxamyl (10G) | 1.12 | 2 | 89.65 | 2 | −5.36 |
| Oxamyl (10G) | 1.68 | 1 | 44.20 | 1 | −4.88 |
| Oxamyl (10G) | 4.5 | 1 | 91.00 | 1 | 9.00 |
| Terbufos (15G) | 1.12 | 5 | 22.96 | 3 | 0.80 |
| Terbufos (15G) | 1.68 | 1 | 58.90 | 1 | 0.00 |
| Average | | | 45.21 | | 0.24 |

[a] Response represents comparisons made between nematode numbers or yields on treated plots and non-treated plots. A (−) nematode response means nematode counts were higher in treated plots than non treated; a (−) yield means yield in treated plots was lower than yield in non-treated plots.

bu/a). There appears to be no correlation between yield and nematode control in our sites because several chemicals controlled nematodes effectively but gave no yield response (Table 3). Data obtained from research at two other locations in western Kansas by Lash and Dickerson (1979) also showed little correlation in nematode numbers and yield.

Stunting was observed in some locations in both 1978 and 1979. Stunting, when observed, was continuous throughout all plots and appeared due to water stress and not nematodes. Essentially all corn in western Kansas is irrigated. Many times conditions arise where improper irrigation places water-stress conditions on corn. Nematode damage may be associated with stress conditions (J. D. Smolik, personal communications), yet even in locations in which water stress occurred we could not show increased yields due to nematode reduction. It was also noted that in some locations in which water stress occurred, nematode populations were lower, and treatments resulted in a smaller percentage of population reduction than in nonstressed locations.

The results of our tests indicate that 1) fairly high populations of nema-

todes (in particular *Pratylenchus* spp.) are normal in corn in western Kansas; 2) chemical treatments effectively reduce nematode populations; but 3) nematode control does not influence corn yields.

The application of a nematicide to corn in western Kansas does not appear to be economically favorable at this time.

## Literature Cited

Bergeson, G. B. 1978. Control of the lesion nematode (*Pratylenchus* spp.) in corn with carbofuran. Plant Dis. Rep. 62:295–297.

Dickerson, O. J. 1971. An evaluation of the direct centrifugal flotation method of recovering nematodes from soil. Plant Dis. Rep. 61:1054–1057.

Johnson, J. T., and D. W. Dickson. 1973. Evaluation of methods and rates of application of three nematicide-insecticides for control of the sting nematode on corn. Soil Crop Sci. Soc. Fla. Proc. 28:262–265.

Lash, L.D. and O. J. Dickerson. 1979. Fungicide and nematicide tests: 34. pp. 189–191.

Norton, D. C. 1978. Corn nematode populations and biogeography. Proc. Midwest Corn Nematode Conf. p. 27–38.

Norton, D. C., and P. Hinz. 1976. Relationship of Hoplolaimus galeatus and *Pratylenchus hexincisus* to reduction of corn yields in sandy soils of Iowa. Plant Dis. Rep. 60:197–200.

Rhoades, H. L. 1968. Effect of nematicides on yield of field corn in central Florida. Soil Crop Sci. Soc. Fla. Proc. 28:262–265.

Rhoades, H. L. 1978. Influence of nonfumigant nematicides and DBCP on *Belanolaimus longicaudatus* and yield of field corn in central Florida. Plant Dis. Rep. 62:91–94.

Shurtleff, M. C. 1973. A compendium of corn diseases. The American Phytopathological Society, Inc., St. Paul, Minn. 64 pp.

Sim, T. 1979. Summary of plant disease conditions in 1978. 62nd Annual Report and Farm Facts, Kansas State Board of Agriculture: 20–25.

Smolik, J. D. 1975. Nemas. S. D. Farm Home Res. 26:5–9.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
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# Germination and Viability of Seeds from 2,4-D Treated Sunflowers and Ragweeds[1]

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## ABSTRACT

Low dosages of 2,4-D increase yields of sunflower seeds but not seeds of ragweeds. This study was conducted to determine germination and viability of seeds produced by sunflowers and ragweeds exposed to low dosages of 2,4-D. Fewer seeds from sunflower plants dosed with 100 ppm of 2,4-D germinated than from plants dosed with 50 ppm or no 2,4-D. No differences were detected in germination rates of ragweed seeds from treated or untreated plants. No treatment-related effects were detected on seed viability.

Pletscher and Robel (1979) reported increased yields of sunflower (*Helianthus annuus*) but not ragweed (*Ambrosia artemisiifolia*) seeds after spraying plants with low dosages of 2,4-D. They theorized that low dosages of synthetic auxins might increase food supplies for granivores but they did not determine germination rates and viability of seeds produced by the plants they sprayed. This report presents results of germination and viability tests on seeds collected during the Pletscher and Robel (1979) study.

## MATERIALS AND METHODS

The study of Pletscher and Robel (1979) was conducted on the Fort Riley Military Reservation in northeastern Kansas. Johnson and Robel (1968) described important plant associations on the Fort. We used ragweed and sunflower seeds produced on Pletscher and Robel's untreated (control) and treated plots, collected in the fall of 1976, stored frozen until April 1979, then removed from the freezer and held at room temperature until germination and viability tests were initiated in October 1979. Treatments were 50 and 100 ppm of 2,4-D sprayed at 0.1 liter/m$^2$ (approximately 0.05 and 0.10 kg acid equivalent per hectare or 10 to 20% of the recommended ap-

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Table 1. Germination rates and viability of sunflower and ragweed seeds produced by 2,4-D treated plants.

| | 2,4-D treatment | | |
|---|---|---|---|
| | Control | 50 ppm | 100 ppm |
| Sunflower seeds | | | |
| Germination | | | |
| Number (of 400 seeds) | 12 | 15 | 5 |
| Percent | 3.0 | 3.8 | 1.3 |
| Timing (mean days) | 7.5 | 6.5 | 5.6 |
| Viability | | | |
| Number (of 60 halves) | 5 | 0 | 1 |
| Percent | 8.3 | — | 1.7 |
| Ragweed seeds | | | |
| Germination | | | |
| Number (of 400 seeds) | 11 | 5 | 8 |
| Percent | 2.8 | 1.3 | 2.0 |
| Timing (mean days) | 7.6 | 7.8 | 8.4 |
| Viability | | | |
| Number (of 60 halves) | 22 | 27 | 29 |
| Percent | 36.7 | 45.0 | 48.3 |

plication rate for weed control). Pletscher and Robel (1979) described field treatment procedures.

We used 400 seeds each of sunflower and ragweed from each of three treatment regimes (control plus two 2,4-D treatments) in the germination tests. Seeds were placed on 3 pieces of water-saturated, medium porosity filter paper in Petri dishes (20 seeds per dish), covered with lids, and placed in an incubator at 22°C and 12D:12L photoperiod (Lobanov, 1967:21). Seeds were checked daily for evidence of germination. Seeds producing a radicle longer than seed length within 14 days were termed germinated.

Thirty seeds each of sunflower and ragweed from each of three treatment regimes (control plus two 2,4-D treatments) were used in the viability tests. Seeds were soaked in distilled water at room temperature for 5 hours, cut in half longitudinally, placed on filter paper in Petri dishes (12 halves per dish), then covered with 10 ml of 0.5% solution of tetrazol (2,3,5-triphenyl-tetrazol) and examined after 1.5 hours for evidence of viability (Lobanov, 1967:31). Seed halves with red colored embryos, radicles, or sprouts were termed viable.

## Results

More ($P < 0.05$) sunflower seeds germinated from plants on control plots (no 2,4-D exposure) and from plants treated with 50 ppm of 2,4-D than from

plants treated with 100 ppm of 2,4-D (Table 1). Although mean generation times decreased as 2,4-D dosage increased, the relationship was not significant ($P > 0.05$). Sunflower viability results were inconsistent with germination results, i.e., no seeds from plots treated at 50 ppm were considered viable but 3.8% of those seeds germinated (Table 1).

No differences ($P > 0.05$) were detected in germination rates of ragweed seeds produced by plants on control and on treated plots (Table 1). Nor were differences ($P > 0.05$) detected in germination times between ragweed seeds from control and treated plots. Viability of ragweed seeds ranged from 37 to 48% with no treatment-related differences detected.

## Discussion

The 1.3 to 3.8% germination rates of sunflower and ragweed seeds tested in this study appear low. Germination rates of wild sunflower seeds tested by the Kansas State Board of Agriculture during 1976 ranged from 9 to 95% (C. M. Webster, 1980, Seed Lab., Kansas State Board Agric., Topeka, KS, pers. commun.). No comparable data are available for ragweed seeds. The low germination rates of the seeds collected during the Pletscher and Robel (1979) study could have accurately reflected either the germination ability of seeds produced on the site that year or desiccation of seeds during 2 years' storage at subzero temperatures. The lack of viable sunflower seeds in the 30-seed sample from the 50 ppm treatment plots could have been a chance event stemming from low viability of sunflower seeds from plants on all plots. Low germination rates (1.3 to 2.8%) of ragweed seeds compared with 37 to 48% viability support the hypothesis that germination ability of ragweed seeds and both germination ability and viability of sunflower seeds were adversely affected by desiccation during storage.

Even though the germination ability and viability of the sunflower and ragweed seeds produced during the Pletscher and Robel (1979) study may have been reduced during storage, no evidence indicated that reductions were related to treatments. Therefore, the lack of effect of 2,4-D on germination rates and viability of sunflower and ragweed seeds may be valid.

## Literature Cited

Johnson, S. R., and R. J. Robel. 1968. Caloric values of seeds from four range sites in northeastern Kansas. Ecology 49:956–961.

Lobanov, V. Y. 1967. Quality determination of seeds. Israel Prog. Sci. Translations. Jerusalem, Israel. 72 pp.

Pletscher, D. H., and R. J. Robel. 1979. Possible use of 2,4-D management of sunflower and ragweed. Wildl. Soc. Bull. 7:48–53.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
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# New Locality Records for Some Kansas Fishes, With Notes on the Habitat of the Arkansas Darter (*Etheostoma cragini*)

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ABSTRACT

*Etheostoma cragini* is reported from three new localities in atypical habitat. *Notropis umbratilis* is reported for the first time from Jefferson County; *Notropis buchanani* is added to the Walnut River ichthyofauna; and *Aplodinotus grunniens* is reported from the Arkansas River in Kansas for the first time.

The ichthyofauna of Kansas is well known through the work of Cross (1967) and co-workers (Cross and Collins, 1975; Collins and Caldwell, 1978; Collins, 1979). Fieldwork by us from 12–16 June 1978 extended the known distributions of several species in Kansas, and provided additional information on habitats used by a species of special interest.

## *Etheostoma cragini* (Arkansas Darter)

*Etheostoma cragini* is endemic to the Arkansas River basin, typically occurring in isolated colonies in small spring runs that are overgrown with watercress (Cross, 1967; Cloutman, 1970). The vulnerability of such habitats in Kansas and Oklahoma led Blair (1959) and Cross and Collins (1975) to express concern for the species. Platt et al. (1973) recommended *E. cragini* be given special attention to insure its survival. The species was designated as threatened in Kansas in 1978 by state law.

Despite the affinity of *E. cragini* for spring habitats, Cross (1967) noted its ability to temporarily withstand unfavorable environments, citing his capture of one specimen from the mainstream of the Arkansas River. Cloutman (1970) indicated *E. cragini* might be tolerant of fluctuating water levels and sluggish currents, but believed it intolerant of turbid water.

On 14 June 1978 we collected one *E. cragini* (25 mm S.L.; WJM 313; KU 18629) from Rattlesnake Creek, at U.S. Rt. 281, 6 km north of St. John,

Stafford County. The creek, which drained pastureland, was 10–15 m wide and approximately one meter deep, with a mud bottom. Banks were of dirt and sand; the water was very turbid. The specimen was taken near shore where there was no flow. Fishes collected with *E. cragini* were 112 *Notropis lutrensis*, three *Notropis stramineus*, and one *Cyprinus carpio*. *Etheostoma cragini* has been taken previously at three other localities within Rattlesnake Creek watershed (KU 12184, 16049, and 16821).

On 15 June 1978 we collected one *E. cragini* (26 mm S.L.; WJM 320; KU 18630) from the mainstream of the Arkansas River at Oxford, Sumner County. Cross (1967) previously took one *E. cragini* (KU 3470) from the river near this locality; this is the second report of the species from the Arkansas River. The darter was captured in moderate current over a silty sand bottom near shore, in approximately one meter of water. The mainstream at this location was deep and swift, approximately 200 m wide, and highly turbid. Associated with the darter were 7 *N. lutrensis*, 1 *P. vigilax*, 2 *Notropis atherinoides*, 1 *Dorosoma cepedianum*, and 1 *Aplodinotus grunniens*.

We collected one specimen of *E. cragini* (27 mm S.L.; WJM 318; KU 18631) from the Chikaskia River at the U.S. Rt. 160 bridge at the Harper-Sumner county line on 15 June 1978, representing the first capture of the species from the river proper. The species has been taken previously in the Chikaskia River drainage at Sand Creek near Zenda, Kingman County, (KU 16950), and from a branch of Bluff Creek, Harper County (Cross, 1967).

The stream drained pastures at this locality, and averaged 40 m wide with depths in excess of one meter. The water was clear, over unstable sand bottoms. Some grasses were at the water's edge, but there were no indications of nearby springs. In this collection we also took 94 *N. lutrensis*, 3 *N. stramineus*, 4 *Campostoma anomalum*, and one specimen each of *Pimephales vigilax* and *Gambusia affinis*.

All three of these collections of *E. cragini* were in habitats that differed markedly from that considered typical for the species. The specimens could represent waifs from unknown nearby springs, but during the days immediately prior to our collecting there had been no rains of a magnitude likely to flush fish from small tributaries into mainstreams. These collections thus reinforce the concept that *E. cragini* can survive in sub-optimal habitats (Cross, 1967). The collections in the Arkansas River and Rattlesnake Creek suggest that, in contrast to the opinion of Cloutman (1970), the species may be able to survive, at least temporarily, in turbid environments. This ability could be critical to the survival of the species during droughts if spring runs become desiccated.

### *Aplodinotus grunniens* (Freshwater Drum)

In the same collection (WJM 320) in which we took an *E. cragini* from the Arkansas River at Oxford, Sumner County, we captured a single juvenile

*Aplodinotus grunniens* that was 15 mm S.L. (KU 18632). This collection is the first of this species from the Arkansas River mainstream, although it has been collected in tributaries within the drainage (Cross, 1967).

### *Notropis umbratilis* (Redfin Shiner)

On 12 June 1978 we collected one adult *Notropis umbratilis* (WJM 295; KU 18633) from an unnamed creek just west of Williamstown, Jefferson County. This stream, primarily a channelized ditch, is a northern tributary of the Kansas River. *Notropis umbratilis* has rarely been reported from tributaries north of the Kansas River (Cross, 1967), and this is the first record of the species in Jefferson County.

### *Notropis buchanani* (Ghost Shiner)

We collected four *N. buchanani* (WJM 322; KU 18634) on 15 July 1978 from the Walnut River 300 m downstream from a dam at the southwest edge of Winfield, Cowley County. Although Metcalf (1959) thoroughly surveyed this area, *N. buchanani* was not reported from the Walnut River drainage. It has been taken nearby in Grouse Creek (Cross, 1967) and in the Arkansas River, Sumner County (KU 12194).

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## Literature Cited

Blair, A. P. 1959. Distribution of the darters (Percidae, Etheostomatinae) of northeastern Oklahoma. Southwest Nat. 4(1):1–13.

Cloutman, D. G. 1970. Notes on the distribution of the Arkansas darter, *Etheostoma cragini* Gilbert, with a new record from Bluff Creek, Clark County, Kansas. Trans. Kansas Acad. Sci. 73(4):431–433.

Collins, J. T. 1979. New records of fishes, amphibians and reptiles in Kansas for 1978. Tech. Publ. State Biol. Surv. Kansas 8:56–66.

Collins, J. T., and J. Caldwell. 1978. New records of fishes, amphibians in Kansas for 1977. Tech. Publ. State Biol. Surv. Kansas 6:70–88.

Cross, F. B. 1967. Handbook of fishes of Kansas. Univ. Kansas Mus. Nat. Hist. Misc. Publ. 45:1–357.

Cross, F. B., and J. T. Collins. 1975. Fishes in Kansas. Univ. Kansas Mus. Nat. Hist. Pub. Ed. Ser. 3:1–189.

Metcalf, A. L. 1959. Fishes of Chautauqua, Cowley and Elk counties, Kansas. Univ. Kansas Publ. Mus. Nat. Hist. 11(6):345–400.

Platt, D. R., F. B. Cross, D. Distler, O. S. Fent, E. R. Hall, M. Terman, J. Zimmerman, and J. Walstrom. 1973. Rare, endangered and extirpated species in Kansas. I. Fishes. Trans. Kansas Acad. Sci. 76(2):97–106.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
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# An Observation of Snake Predation on a Bat

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On 14 April 1979, at 0930 CST, a black rat snake (*Elaphe obsoleta obsoleta*) was observed rolling down a leaf-strewn slope along the Upper Jack's Fork River in Texas County in south central Missouri. Upon closer inspection a grayish bat was observed among the coils of the snake. We began monitoring the struggle between the two animals and recorded the event on film. Although the bat was not identified at the time, a distinct keel was observed on the calcar in one of the photographs. Given the fur coloration, the physical characteristics of the foot and the calcar, and the geographic location, it is probable that the prey of the black rat snake was an Indiana bat (*Myotis sodalis*).

The bat was alive and struggling when first observed. From 0930 to 0932 CST the rat snake continued to constrict its prey. At 0933 CST, the bat appeared to be dead. The snake consumed the bat head first, a process that took nine minutes, with the membraneous wings of the bat being the last body segments to be devoured. The entire event spanned eleven minutes. The rat snake remained stationary for six more minutes, and then crawled into the leafy cover at the base of a tree.

The encounter between snake and bat apparently had begun further up the slope since our first sighting was the movement of them rolling downhill. The two animals were approximately ten meters from numerous rocky outcroppings and 100 meters from a cave entrance. The timbered hillside contained several large dead trees. In summer, Indiana bats roost under loose bark and in hollows of trees (Humphrey et al., 1977), but some males spend the summer around hibernacular caves (Hall, 1962; Myers, 1964). Based upon this information and the knowledge that black rat snakes are both arboreal and enter caves, we speculate that the bat was hibernating or roosting in one of the suitable retreats. Because of the probable torpid condition of the bat, it was readily available prey for the snake.

Several animals are known to prey upon bats. A leopard frog (*Rana pipiens*) captured and consumed a *Myotis* (Barbour and Davis, 1969). Rat snakes have captured bats in caves in Kentucky (Barr and Norton, 1965) and in Kansas (Collins, 1974). This paper documents a black rat snake effectively preying upon an Indiana bat in Missouri.

## Literature Cited

Barbour, R. W., and W. H. Davis. 1969. Bats of America. University Press of Kentucky, Lexington, 286 pp.

Barr, T. C., Jr., and R. M. Norton. 1965. Predation on cave bats by the pilot black snake. J. Mammal. 46:672.

Collins, J. T. 1974. Amphibians and reptiles in Kansas. Univ. Kansas Mus. Nat. Hist. Pub. Ed. Ser. 1:1–283.

Hall, J. S. 1962. A life history and taxonomic study of the Indiana bat, *Myotis sodalis*. Reading Public Mus. and Art Gallery, Sci. Publ. 12:1–68.

Humphrey, S. R., A. R. Richter, and J. B. Cope. 1977. Summer habitat and ecology of the endangered Indiana bat, *Myotis sodalis*. J. Mammal. 58(3):334–346.

Myers, R. F. 1964. Ecology of three species of myotine bats in the Ozark Plateau. Doctoral Dissertation, Univ. of Missouri, Columbia, 210 pp.

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# First Record of *Cordylophora lacustris* Allman from Kansas

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ABSTRACT

*Cordylophora lacustris* Allman, a unique colonial hydroid coelenterate usually abundant in brackish waters, was collected from Melvern Lake, Osage County, Kansas, on 14 September and 3 October 1980. Those collections constitute a first record for Kansas.

Since *Cordylophora lacustris* Allman is abundant in brackish waters and has been collected only occasionally from fresh waters, it has been assumed that this unique colonial hydroid coelenterate is a brackish-water animal in the process of evolving into a fresh-water form (Carpenter, 1928; Wesenberg-Lund, 1939). Reports of infrequent collections of *C. lacustris* from fresh waters in the Western Hemisphere have been made, but many of those earlier collections are only doubtfully non-brackish (Clarke, 1878; Bibbens, 1892; Nutting, 1901; Hargitt, 1908; Gaggero, 1923 and 1935). However, Davis (1957) cited records of the collection of this organism prior to 1957 from Benson Creek, Kentucky, Gatun Locks in Panama, Fairmount Reservoir in Pennsylvania, the Schuylkill River in Kentucky, the Illinois and Mississippi Rivers in Illinois, the Arkansas River at Little Rock and the Red River at Shreveport, Louisiana, along with his collection from the mouth of the Chagrin Harbor, Ohio, as coming from incontestable fresh waters. I agree that all of those bodies of water are classified as fresh, but I do not agree that all have a low salt content. Both the Arkansas and Red Rivers are bedded in soils of high salt content, and they have tributaries that actually course over exposed salt deposits. One tributary of the Arkansas River, the Salt Fork of the Arkansas River, crosses the Great Salt Plains in Alfalfa County, Oklahoma, and is impounded to form the Great Salt Plains Lake near Cherokee. Ransom (1968) collected *C. lacustris* 21 times in a total of 1232 Ekman dredge hauls from the Cimarron arm of Keystone Reservoir near Tulsa, Oklahoma. The Arkansas River forms the other main arm of the reservoir. Specific conductance in Keystone Reservoir at the time of the collections ranged from 1700 to 12,000 $\mu$mhos/cm and was due mostly to a high sodium chloride concentration. Hutchinson (1967) stated that although the data are

incomplete *C. lacustris* generally has been found in inland waters of relatively high salt content. I see no reason to question his statement in 1980.

Pennak (1953) reported *C. lacustris* occurred in brackish inlets and estuaries from New Jersey to the Gulf of the St. Lawrence and that it has been collected in inland rivers in Illinois, Arkansas and Louisiana, probably the same collections as those reported by Davis (1957). Isom and Sinclair (1962) reported collections of *C. lacustris* from the Tennessee, Cumberland and Duck Rivers from 1955 through 1962. There is a published record of an earlier collection than the one from Keystone Reservoir in Oklahoma and that was from a flume near Tulsa (Blair, 1964).

I collected a large number of specimens of *C. lacustris* from Melvern Lake, Osage County, Kansas, on 14 September 1980, and on 3 October 1980. Since those dates, I have observed the organism many times at the same location. The present find is the first record of this species in Kansas. Specimens were taken from depths ranging from 2 to 10 meters and they were attached to sumerged roots removed by a boat anchor and to *Potamogeton* stems. The collected specimens are in my personal collection and representatives have been delivered to The Kansas State Biological Survey, University of Kansas.

Melvern Lake is without question a clear, fresh body of water. The salt content is very low, with a conductivity ranging between 150 and 400 $\mu$mhos/cm. A Secchi disc reading on 3 October 1980, was more than 110 cm at the collecting site. The 1980 *C. lacustris* collections from Melvern Lake were unquestionably fresh-water specimens.

## Literature Cited

Bibbens, A. 1892. On the distribution of *Cordylophora* in the Chesapeake estuaries and the character of its habitat. Trans. Maryland Acad. Sci. 1:213–228.

Blair, A. P. 1964. *Cordylophora lacustris* and *Craspedacusta sowerbyi* (Cnideria: Hydrozoa) in Oklahoma. Southwest. Nat. 9(2):109.

Carpenter, K. E. 1928. Life in inland waters. Macmillan Co., N.Y. pp. 1–18.

Clarke, S. F. 1878. A new locality for *Cordylophora*. Amer. Nat. 12:232–234.

Davis, C. 1957. *Cordylophora lacustris* Allman from Chagrin Harbor, Ohio. Limnol. and Oceanog. II: pp. 158–159.

Gaggero, P. 1923. *Cordylophora lacustris* Allman en el Rio de la Plata. Ann. Soc. Cient. Argentina 96:264–268.

Gaggero, P. 1935. *Cordylophora lacustris* in the River Plate. Verh. Intern. Ver. Limnol. 7(2):464–465.

Hargitt, C. W. 1908. Notes on a few coelenterates of Woods Hole. Biol. Bull. 14:95–120.

Hutchinson, G. E. 1967. A treatise on limnology. Vol. II: Introduction to lake biology and the limnoplankton, pp. 38–39. John Wiley and Sons, Inc., N.Y.

Isom, B. G., and R. M. Sinclair. 1962. Fresh-water coelenterates in Tennessee; new distribution records for: I. *Craspedacusta sowerbyi* Lankester 1880; II. *Cordylophora lacustris* Allman 1871. Tennessee Stream Pollution Control Board, Publication No. 9.

Nutting, C. C. 1901. The hydroids of the Woods Hole region. Bull. U.S. Fish Comm. 1899:325–386.

Pennak, R. W. 1953. Fresh water invertebrates of the United States, pp. 105–106. The Ronald Press Co., N.Y.

Ransom, J. D. 1968. *Cordylophora lacustris* (Coelenterata: Hydrozoa) comparatively abundant in Keystone Reservoir, Oklahoma. Southwest. Nat. 13(1):107.

Wesenberg-Lund, C. 1939. Biologie der Susswassertiere. Wirbellose Tiere. Julius Springer, Vienna. pp. 1–11, 1–817.

TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCES
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# *Enteromorpha*, a Marine Alga in Kansas

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*Enteromorpha* Link is primarily a marine genus that has been occasionally reported from inland salt springs and some inland lakes with high salt concentrations (Collins, 1909; Smith, 1950). In contrast to marine species, the mature thalli of most freshwater *Enteromorpha* consist of long, usually branched, hollow tubes with a wall one cell in thickness (Fig. 1). Only two species of *Enteromorpha* have been previously reported from Kansas, each on the basis of a single collection. The first was *E. intestinalis* (L.) Link from Cheyenne Bottoms in Barton County, by McFarland et al. (1964) and the second was *E. prolifera* (Muell.) Ag. from the Big Salt Marsh part of the Quivira National Wildlife Refuge in Stafford County, by Reinke (1977) and is now referred to subsp. *prolifera*. Recent reports of *Enteromorpha* from Oklahoma (Vinyard, 1966; Pfiester et al., 1976; Conner et al., 1978) exemplify that the inland distribution is poorly known. A total of three species (*E. compressa* (L.) Greville, *E. torta* (Mert) Reinbold and *E. flexuosa* (Wulfen ex Roth) ag. [=*E. prolifera* var. *tubulosa* (Kuetz.) Reinbold] have been reported from Oklahoma each on the basis of a single collection. However, Pfiester et al. have suggested that *Enteromorpha* is probably more common in inland areas than previously believed. *E. prolifera* subsp. *prolifera* has also been collected in Nebraska (Keith County, 7 mi NE Ogallala below Lake McConaughy, 20 Sept. 1978 by R. Brooks s.n.).

Fieldwork by the State Biological Survey of Kansas has added 16 additional collection sites for *E. prolifera* (Muell.) Ag. subsp. *prolifera* in Kansas and supports the suggestion that *Enteromorpha* is more common than would be indicated by the algal literature. *E. prolifera* subsp. *prolifera* differs from *E. compressa*, *E. torta* and *E. flexuosa* by having a smaller cell size (9–18 × 6–12 $\mu$) in the mature thallus, square to rectangular cells, and the cells arranged in distinct longitudinal rows.

The new specimen records from Kansas are: 1) Dry Lake, Scott County, 6 mi S and 8 mi E Shallow Water, 19 July 1977, D. Reinke #53; 2) Crooked Creek, Meade County, 17½ mi S and 7½ mi E Meade, 3 Aug. 1979, D. Reinke #83; and 14 mi S Meade, 23 Sept 1980, D. Reinke 440; 3) a spring fed marsh, Pratt County, ½ mi N Cario, 30 April 1978, D. Huggins and P. M. Liechti #3; 4) Big Sandy Creek, Clark County, 10 mi S Ashland, 23 Sept. 1980, D. Reinke #443; 5) Salt Creek, Rice County, 3 mi S Raymond, 21 Oct 1980, D. Reinke #469; and 6) Willow Creek, Wallace County, SE ¼, Sec 12, T13S, R42W, 9 Jul 1980, McGregor #31829. Dry Lake is a stilling

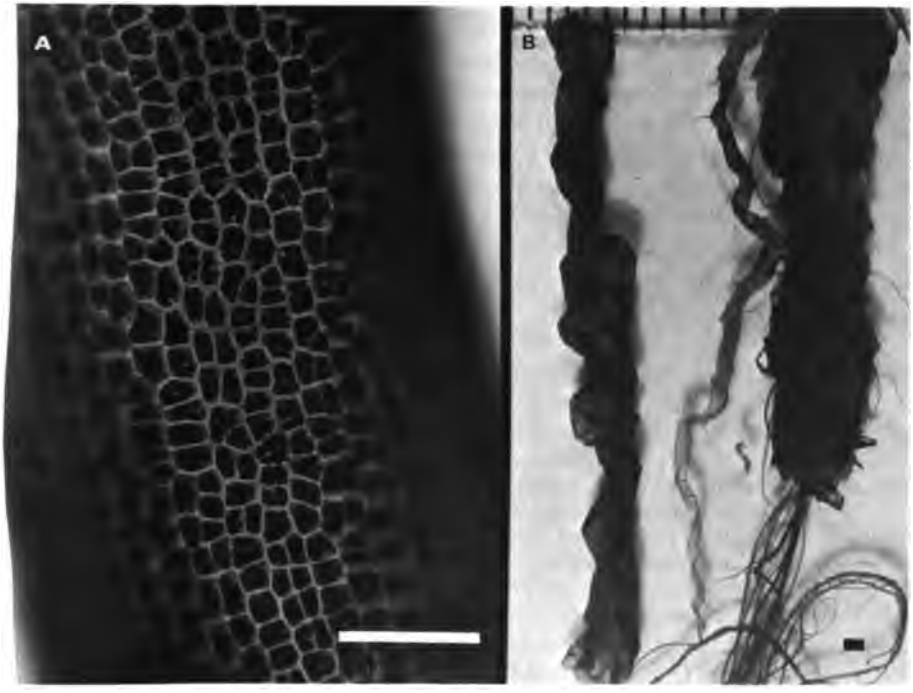


Fig. 1. (A) Mature thalles showing cell shape and longitudinal cell arrangement. White scale = 50 $\mu$m. (B) Sections of 3 thalli showing size and branching characters. Black scale = 1 mm.

basin with no out flow and by late summer usually has extensive mud flats with crystallized salt particles. Crooked Creek also has a history of high salt concentrations (USGS, 1979) especially during the late summer and early fall months. Big Sandy Creek and Salt Creek had the highest measured conductivity (3200 and 10,000 micromhos/cm) of all the collection sites. Unfortunately there are no chemical data available on the spring fed marsh in Pratt County; however, salt grass (*Distichlis spicata*) is common in that region, indicating some degree of soil alkalinity is present. The Willow Creek station would appear to be the collection site with the lowest salinity, but no parameters were taken when the collection was made.

The nine remaining stations are all located on the Arkansas River. The average conductivity and pH for these collections were 1962.5 and 8.1, respectively. The collection sites by county were: 1) Barton County, 1 mi S Ellinwood, 21 Oct 1980, D. Reinke #467; 2) Cowley County, West edge Arkansas City, 22 Oct 1980, D. Reinke #447; 3) Reno County, S. Hutchinson, HW-61 Arkansas River bridge, 24 Sept 1980, D. Reinke #447 and S. Hutchinson HW-96 Arkansas River bridge, 1 July 1980, A. Slater #131; 4)

Rice County, 2½ mi S Sterling, 21 Oct 1980, D. Reinke #470 and 2 mi N Mount Hope, 22 Oct 1980, D. Reinke #473, and ½ mi S Raymond, 21 Oct 1980, D. Reinke #468; and 5) Sumner County, 5 mi E Belle Plaine, 22 Oct 1980, D. Reinke #479 and ¼ mi E Oxford, 22 Oct 1980, D. Reinke #476. Kansas has many waters with high salt concentrations and examination of long algal strands especially in areas of high salinity will undoubtedly add additional records of *Enteromorpha*.

The preserved samples of *Enteromorpha* are on deposit in the State Biological Survey Algal Collection, Lawrence, Kansas.

## Literature Cited

Bliding, C. 1963. A critical survey of the European taxa in Ulvales Part 1. *Capsosiphon, Percursaria, Blidingia, Enteromorpha*. Opera Botanica 8:1–160.

Collins, F. S. 1909. The Green Algae of North America. Tufts College Stud. Sci. Ser. 2:79–480.

Conner, D., D. J. Huddleston, L. A. Pfiester, and S. Thompson. 1978. A third species of *Enteromorpha* (a marine chlorophycean) for Oklahoma. Proc. Okla. Acad. Sci. 58:110.

McFarland, H. J., E. A. Brazda, and D.H. McFarland. 1964. A preliminary survey of the algae of Cheyenne Bottoms in Kansas. Fort Hays Stud. Sci. Ser. 2:1–80.

Pfiester, L. A., O. P. Felkner and W. O. Felkner. 1976. *Enteromorpha*, a marine alga in Oklahoma. Proc. Acad. Sci. 56:66.

Reinke, D. C. 1977. Algae new to the state of Kansas from the Big Salt Marsh, Stafford County, Kansas. Tech. Publ. State Biol. Survey Kansas 4:1–6.

Smith, G. M. 1950. The Fresh-water Algae of the United States. 2 ed. McGraw-Hill Book Co. New York. 719 pp.

United States Geological Survey, 1979. Water Resources Data for Kansas. KS-78-1. 656 pp.

Vinyard, Wm. C. 1966. Additions to the algal flora of Oklahoma. Southwest. Nat. 11:196–204.

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